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Waste Stabilization Lagoon Microorganism Removal Efficiency and Effluent Disinfection with Chlorine

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16. ABSTRACT

This project had two major objectives: (1) to evaluate the amenability of algae-laden lagoon effluent to chlorine disinfection; and (2) to evaluate the performance of a multi-cell lagoon system in removing coliform bacteria by natural means without the need for disinfection.

Results indicate that adequate disinfection was obtained with combined chlorine residual within a contact period of 60 minutes. Filtered effluent was found to exert less chlorine demand than unfiltered. Temperature, sulfide, and total chemical oxygen demand were the most important factors affecting the chlorine dose necessary to achieve a specified bacteriological quality. A mathematical model was developed and a series of design curves were constructed for use in selecting the optimal chlorine dosages needed for achieving prescribed levels of disinfection.

Total and fecal coliform removal in the lagoon system was related to hydraulic residence time. Coliform die-away rate was 16 times greater in summer months than in winter months.

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WASTE STABILIZATION LAGOON MICROORGANISM REMOVAL EFFICIENCY AND EFFLUENT DISINFECTION WITH CHLORINE

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

As part of these activities, this report was prepared to make available to the sanitary engineering community a full year of operating and measured performance data for wastewater stabilization lagoon coliform die-away and the effects of chlorination on lagoon effluent quality.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

Chlorine disinfection of waste stabilization lagoon effluents has been and is being considered a solution to bacterial removal prior to discharge to receiving waters. To evaluate the amenability of algae-laden lagoon effluent to chlorine disinfection, chlorination test facilities were constructed at the Logan, Utah, wastewater lagoons. An investigation was conducted at these facilities on primary and secondary, as well as filtered and unfiltered, lagoon effluents between August 1, 1975, and August 24, 1976. The filtered effluent was obtained by passing lagoon effluent through an intermittent sand filter prior to chlorination.

The results of this study indicate that, in all cases, adequate disinfection was obtained with combined chlorine residual within a contact period of 60 minutes or less. Filtered effluent was found to exert less chlorine demand than unfiltered effluent. It was also determined that temperature, sulfide, and total chemical oxygen demand influence the chlorine dose necessary to achieve a specified level of disinfection. Suspended solids and soluble chemical oxygen demand were found to be slightly altered as a result of chlorination.

A mathematical model was developed to represent the effects of chlorination of lagoon effluents. This model was used to predict the chlorine dosages necessary to achieve adequate disinfection for varying effluent characteristics. A series of design curves were constructed from the model for use in selecting the optimal chlorine dosages necessary for achieving prescribed levels of disinfection.

A second objective of the study was to evaluate the performance of the Logan multi-cell lagoon system in removing coliform bacteria by natural means without the need for disinfection. Both total and fecal coliform removal in the lagoon system was related to hydraulic residence time. A coliform die-away coefficient for summer months and winter months of 0.5 and 0.03 respectively was determined.

A comparison was made between the membrane filter and Most Probable Number techniques for enumerating coliform bacteria in each cell of the lagoon system. Both techniques appear to show the same trends. Variations in results when analyzing a common sample appear to be equal for both the total and fecal MPN and the MF techniques. However, the absolute numerical value obtained from the two techniques may differ substantially.

This report was submitted in fulfillment of Contract No. 68-03-2151 by Utah State University, Logan, Utah 84322, under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period August 1975 to August 1976, and work was completed as of September 1976.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

BOD = five day biochemical oxygen demand
COD = chemical oxygen demand
Coli = coliform
DDW = deionized distilled water
DO = dissolved oxygen
FC = fecal coliform
gal. = gallon
gpd = gallons per day
gpm = gallons per minute
L = length
l = liter
MF = membrane filter
mg/l = milligram per liter
MI = Morrill Index
min. = minute
ml = milliliter
MPN = Most Probable Number
m^3/day = cubic meters per day
SCOD = soluble chemical oxygen demand
sec = second
TC = total coliform
TCOD = total chemical oxygen demand
Temp = temperature
TKN = total Kjeldahl nitrogen
TOC = total organic carbon
Turb = turbidity
V = volume
VSS = volatile suspended solids
W = width

SYMBOLS

A_i = water surface area of the ith pond
C = concentration at time = t
C_0 = concentration at time = 0
Ca^{++} = calcium ion
$Ca(OCl)_2$ = calcium hypochlorite
CCl = combined chlorine residual
C_{eff} = proportionality constant
Cl = chlorine

Cl_2 = chlorine gas
Cl^- = chloride ion
DQ = change in storage
D_t = chlorine demand at time = t
D_1 = chlorine demand at 1 hour
E = activation energy
FCl = free chlorine residual
Fe^{++} = ferrous ion
H = hydrogen
H^+ = hydrogen ion
HAC = acetic acid
HCl = hydrochloric acid
HOCl = hypochlorous acid
H_2O = water
H_2SO_4 = sulfuric acid
K = empirical constant
K_r = rate constant
K_T = rate of bacterial die-away coefficient at any temperature
K_{20} = rate of bacterial die-away coefficient at 20°C
K_5 = rate of bacterial die-away coefficient at 5°C
Mn^{++} = manganese ion
N = number of organisms at any time
N_o = initial number of organisms
N_a = number of organisms at a minutes
N_t = number of organisms at t minutes
N_2 = nitrogen gas
NaOCl = sodium hypochlorite
NH_4Cl = ammonium chloride
NH_3-N = ammonia nitrogen
NO_2-N = nitrite nitrogen
NO_3-N = nitrate nitrogen
NO_2^- = nitrite ion
OCl^- = dissociated hypochlorous acid (hypochlorite ion)
Q = flowrate
R = correlation coefficient
S = sulfide remaining after chlorine dose
S_L = lower limit of sulfide detection
S_o = initial sulfide concentration
$S^=$ = sulfide ion
T = Q/V (theoretical detention time)
V_i = capacity of the ith pond
a = a constant
b = a constant
c = chlorine residual
d = dispersion index
e = pan evaporation
k = temperature dependent rate constant
m = slope
n = coefficient of dilution
p = plug flow fraction
t = time
t_i = time for tracer to initially appear at tank outlet

t_p = time for tracer at outlet to reach peak concentration
t_{10}, t_{50}, t_{90} = time for 10, 50, and 90 percent of the tracer to pass at tank outlet
t_g = time to reach centroid of the effluent curve
t_i/T = index of short circuiting
t_p/T = index of modal detention time
t_{50}/T = index of mean detention time
t_g/T = index of average detention time
t_{90}/t_{10} = Morrill Dispersion Index--indication of degree of mixing
V_{eff} = effective volume
X = chlorine dose
y = coliform count at time = t
y_0 = coliform count at t = 0
^oC = degrees centrigrade
^oK = degrees kelvin
θ = constant in Arrhenius equation or hydraulic residence time
ΔSCOD = change in soluble chemical oxygen demand
α = inter-pond flow
β = empirical constant
[ ] = molar concentration
Σ = summation
< = less than
> = greater than

SYMBOLS USED IN CHLOR-I

ANH2CL = combined chlorine, mg/l
ARATIO = ratio of chlorine to NH_3 at T = 0
BHOCLT = empirical constant--define effect of free chlorine on bacteria destruction
BNH2CL = empirical constant--defines effect of combined chlorine on bacteria destruction
CC1-CC9 = empirical rate constants
CFECAL = empirical constant used to describe rate of fecal coliform destruction
CHOCLT = empirical constant used in defining rate of chlorine demand
CLX = the initial amount of free chlorine
CL^y = the initial amount of combined chlorine
CNH2CL = empirical constant used in defining rate of exertion of combined chlorine demand
CORNH3 = an empirical correction factor to change the shape of the breakpoint curve to compensate for the reaction of chlorine with organic nitrogen
CTCOD = empirical constant used in defining rate of chlorine demand
CTOTAL = empirical constant used to describe rate of total coliform destruction
CV = coefficient of variation
DT = the time step used in calculating the dependent variable (min.)
F = an empirical constant which specifies the settling fraction of SS which will settle out in a plug flow reactor

HOCLT = free chlorine, mg/l

NH3T = total ammonia, mg/l

NN = the number of times the program is to be run

PRI = a print command which specifies at what time interval an answer is to be printed out

RSQ = R squared

SRATIO = the ratio of moles chlorine consumed per mole of sulfide consumed

STDE = standard error

T = time, the independent variable, minutes

TADJ = the temperature adjustment factor to account for the changes in bacterial kill with changing temperature

TADJ2 = the temperature adjustment factor to compensate for changes in the rate at which chlorine demand is exerted with changing temperature

TFIN = a control command specifying the length of time for which the simulation is to be made

SYMBOLS USED IN CHLOR-II

C1-C9 = rate constants, breakpoint reactions

CC4-CC9 = rate constants developed in CHLOR-I

DT = the initial step size

DTMIN = the minimum step size that should be allowed

DTOUT = the interval for printing out the values of dependent variables

DY = the values of the derivatives at the start of the interval

EPS = the error test constant

ERROR = the estimated single step error in each component

JSTART = an initialization indicator, JSTART = -1 means to repeat the last step, JSTART = +1 means take a new step

KFLAG = a completion code, KFLAG = +1 means the step was successful, KFLAG = -1 means the requested error was not achieved

N = the number of first order differential equations

T = the independent variable, time (seconds)

TMAX = the end of the interval being considered

Y = the dependent variables

YMAX = the maximum values of the dependent variables

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SECTION 1

INTRODUCTION

NATURE OF PROBLEM

Waste stabilization lagoons have been used for many years to provide adequate treatment of domestic wastes. Since lagoons require very little operator control and maintenance for successful performance, they have been particularly popular among small and rural communities, where land is relatively inexpensive. However, since passage of the Federal Water Pollution Control Act Amendments of 1972, more stringent discharge standards have been placed on effluent from publicly-owned waste treatment works. The federal secondary effluent standards for waste stabilization ponds, which must be met by 1977, state that the five-day biochemical oxygen demand (BOD_5) shall not exceed an arithmetic mean value of 30 mg/l for effluent samples collected in a period of 30 consecutive days and that effluent suspended solids shall not deteriorate receiving stream quality. No specific effluent suspended solids or fecal coliform bacteria concentration has been established. However effluent suspended solids concentration in general should not exceed an arithmetic mean value of 30 mg/l for effluent samples collected in a period of 30 consecutive days. In addition, the geometric mean of fecal coliform bacteria in the effluent should not exceed 200 per 100 ml for samples collected over seven consecutive days.

Many states have even more stringent requirements than the Federal Government. The State of Utah, for example, has a 1977 effluent standard of 25 mg/l for BOD_5 and SS, along with the geometric mean fecal coliform bacteria limit of 200 per 100 ml in samples collected over 30 consecutive days. By 1980, the Utah standards are to become more stringent and will restrict the arithmetic mean concentration of BOD_5 and SS to 10 mg/l for effluent samples collected over a period of 30 consecutive days. For total and fecal coliform bacteria, the geometric means shall not exceed 200 per 100 ml and 20 per 100 ml, respectively, on effluent samples collected over 30 consecutive days.

There are serious doubts about the ability of most existing waste stabilization lagoons to meet these more stringent requirements. Possible alternatives include improving lagoon efficiency by complete redesign or by adding a disinfection process to final lagoon effluent. Redesign of lagoon systems is generally considered economically impractical. Therefore, disinfection appears to be a promising approach to ensure that lagoon effluents meet the new standards. Because chlorine has been used successfully for many years as a water and wastewater disinfectant and because of its widespread availability and low cost, it is the most obvious choice as a disinfectant.

However, there are many unanswered questions concerning the effects of chlorination of effluents from waste stabilization lagoons.

There is little known concerning the effects of chlorine on algal cells. Recent studies have indicated that concentrations of chlorine necessary to achieve sufficient disinfection may cause the lysis of algal cells, resulting in a release of dissolved organic material to the treated effluent. This in turn may cause the biochemical oxygen demand of the effluent to increase, and thus, defeat one of the purposes of waste stabilization lagoons. Another problem with chlorination is the toxicity imparted to aquatic organisms by inorganic and organic chloramines formed by the reaction of chlorine with ammonia and nitrogenous organic compounds. Discharge of these compounds to receiving waters must be minimized if the ecological balance of the stream is to be preserved. In addition to these problems, there are serious questions concerning the design, operation, and maintenance of lagoon effluent chlorination facilities. Also, there is a lack of information concerning the degree of coliform die-away or physical removal which occurs within the lagoon system. It is possible lagoon systems may be designed in such a manner that lagoon effluent disinfection may not be necessary.

These questions must be answered if regulatory agencies, consulting engineers, and public officials are to have sufficient information to assist them in selecting the most desirable method of upgrading waste stabilization lagoon effluents. Therefore, this study was undertaken with the primary purpose of obtaining data from a field scale investigation under a variety of operating conditions and using this data to develop a procedure for optimizing chlorination of lagoon effluents. In addition, the lagoon hydraulic residence time required to achieve a degree of coliform removal equivalent to disinfection was investigated.

OBJECTIVES

General

The general objective of this investigation was two fold: (1) to determine the amenability of algae-laden lagoon effluent to chlorine disinfection, and (2) to evaluate the natural die-away or removal of bacteria in a well-designed, multi-cell lagoon system to establish whether or not the need exists for lagoon effluent disinfection. A mathematical model was developed to assist in predicting a range of chlorine dose necessary to achieve maximum chlorine disinfection efficiency with a minimum of adverse effects on the overall quality of the lagoon effluent.

Specific

To accomplish the above general objectives the following specific objectives were achieved in connection with a 190 m^3/day (50,000 gpd) chlorination facility located at a seven cell municipal waste stabilization lagoon system:

1. Compile, review, and evaluate the literature pertaining to disinfection of lagoon effluents.

2. Design and construct field scale facilities for providing efficient and effective chlorination of waste stabilization lagoon effluent.

3. Evaluate the performance of the chlorination facility by collecting data at varying chlorine dosages and contact times and under varying seasonal conditions.

4. Determine the effects of algae on the chlorination process by comparing direct chlorination of primary and/or secondary lagoon effluent with "polished" primary and/or secondary effluent which has been filtered through intermittent sand filters before chlorination.

5. Determine the chlorine residual concentrations required to reduce bacterial populations to an acceptable level for the waste stabilization lagoon effluent.

6. Determine the effects of volatile suspended solids, ammonia, and temperature on chlorine residual.

7. Determine the effects of chlorination on lagoon effluent soluble chemical oxygen demand under field chlorination practices.

8. Conduct laboratory investigations for the purpose of determining basic relationships which describe the effects of chlorine on chemical oxygen demand, suspended solids, and other water quality parameters of lagoon effluent.

9. Use the data obtained from field and laboratory studies as well as from literature review to develop a model for predicting performance of the lagoon effluent disinfection process.

10. Compare the model performance with actual field data.

11. Use the model to prepare design curves for chlorination of algae laden waters to determine the chlorine dose required for various levels of disinfection.

12. Determine the lagoon hydraulic residence time required to achieve coliform die-away equivalent to disinfection.

13. Compare the Most Probable Number and Membrane Filter techniques for enumeration of total and fecal coliform bacteria in waste stabilization lagoon systems.

SECTION 2

CONCLUSIONS

The following conclusions concerning the chlorination of waste stabilization lagoon effluent, the removal of coliform bacteria by a waste stabilization lagoon system and the compatibility of the Most Probable Number method and the Membrane Filter method for the enumeration of coliform bacteria in a waste stabilization lagoon system are based on the results of this study.

1. The rate of chlorine disinfection was determined to be a function of chlorine dose and bacterial concentrations.

2. Results indicate increased coliform reduction with increasing chlorine contact times in both the filtered and unfiltered lagoon effluent. Similar results are found in the literature.

3. Greater total and fecal coliform reductions can be obtained with higher concentrations of total chlorine residual in both the filtered and unfiltered lagoon effluent at chlorine contact times of 35 minutes or less.

4. Filtration of algae laden lagoon effluent improves chlorination efficiency by reducing chlorine demand and, therefore, reducing the chlorine dose which must be applied to achieve the desired disinfection result. The reduction in bacterial numbers as a result of filtration also improves chlorination efficiency.

5. Reduction of total and fecal coliform concentrations can be accomplished at lower total chlorine residual levels if the lagoon effluent is filtered through an intermittent sand filter prior to chlorine injection. Filtered lagoon effluent required an average of 42 percent less total chlorine residual than unfiltered lagoon effluent to reduce total coliform bacteria to the same level. An average of 23 percent less total chlorine residual is needed in filtered lagoon effluent to attain the same fecal coliform organism reduction as unfiltered lagoon effluent.

6. In almost all cases, adequate disinfection was obtained with combined chlorine residuals between 0.5 and 1.0 mg/l after a contact period of approximately 50 minutes. This indicates that disinfection can be achieved without discharging excessive concentrations to toxic chlorine residuals into receiving waters.

7. Because of reduced solids and subsequent improvements in effluent quality in the filtered lagoon effluent, the titrable chlorine residual is less likely to be the less bactericidal organic chloramine forms reported in the literature. The chlorine residual remaining in the filtered lagoon effluent consequently is more effective in destroying microorganisms and therefore less residual is required to produce desired coliform reduction levels.

8. Filtered lagoon effluent was found to exert a lower chlorine demand than unfiltered effluent. The difference in chlorine demand between filtered and unfiltered effluent was dependent upon the applied chlorine dose. Approximately 50 percent of the applied chlorine dosage is taken up by materials that create a chlorine demand in both the filtered and unfiltered lagoon effluent. This was attributed to reductions of total chemical oxygen demand and suspended solids. With this observation, the rate of exertion of chlorine demand was determined to be directly related to chlorine dose and total chemical oxygen demand.

9. No apparent difference in chlorine demand can be attained with chlorine contact times that vary from 17 to 50 minutes for either the filtered or unfiltered lagoon effluent.

10. The field data presented in this report are inconclusive on the effect of volatile suspended solids on chlorine demand. However, the data did indicate no increase in chlorine demand with increasing quantities of volatile suspended solids for either the filtered or unfiltered lagoon effluent.

11. Both disinfection efficiency and the exertion of chlorine demand were found to be temperature dependent. The chlorine residual necessary to effect a given coliform reduction increased as temperature decreased.

12. Greater chlorine dosages were required to obtain similar concentrations of total chlorine residual at lower temperatures for unfiltered lagoon effluent. Results show that 83 percent more applied chlorine is needed to disinfect unfiltered lagoon effluent at temperatures less than 5°C than is required to disinfect unfiltered lagoon effluent at temperatures greater than 15°C. Results of this kind were not observed with filtered lagoon effluent. Explanations as to why these temperature relationships were not seen in the filtered lagoon effluent could not be found.

13. Increasing the total applied chlorine dose did not effect a corresponding increase in soluble chemical oxygen demand in the treated effluent, except possibly when sufficient chlorine was added to result in a free chlorine residual (breakpoint chlorination). Even then, the soluble COD increases were only apparent in the unfiltered lagoon effluent. Thus, chlorination of algae-laden lagoon effluent will not create a substantial organic burden to the receiving stream due to algal lysis.

14. In the field data, reductions in suspended solids as a result of chemical reaction with chlorine were found to be of limited importance in comparison with reductions in suspended solids resulting from settling within the chlorine contact chamber. Suspended solids were found to be reduced by 10-50 percent due to settling.

15. Although plug flow reactors are ideal for disinfection, they also have disadvantages because of problems associated with the accumulation and removal of solids.

16. Breakpoint chlorination for waste stabilization lagoon effluent is affected by concentrations of organic nitrogen as well as NH_3-N. The breakpoint is highly variable and reflects quality and quantity changes in effluent characteristics. The reactions to describe breakpoint chlorination for water were found to be insufficient in explaining breakpoint chlorination for wastewater.

17. Under laboratory conditions, chlorination of lagoon effluent resulted in an increase in turbidity and a decrease in suspended solids. These changes were dependent upon the composition and concentration of suspended solids and resulted from the breakdown of suspended particles.

18. Sulfide, produced as a result of anaerobic conditions existing in the lagoons during the winter months, exerts a significant chlorine demand. For sulfide concentrations of 1.0-1.8 mg/l, a chlorine dose of 6 to 7 mg/l was required to produce the same chlorine residual as a chlorine dose of about 1 mg/l for conditions of no sulfide.

19. Breakpoint chlorination was determined to be rarely, if ever, necessary in disinfecting waste stabilization lagoon effluent. For this study, free chlorine residual was observed in less than 6 percent of the data and in almost all of these cases, total and fecal coliform concentrations were reduced to less than 2/100 ml within 18 minutes. Free chlorine residuals were observed during algae blooms when ammonia occurs in low concentrations. However, mean coliform levels were also found to be low during algae blooms, indicating that even when the concentration of ammonia is sufficiently low to allow the breakpoint reaction, disinfection can be achieved in less than 50 minutes contact time without the use of free chlorine residual.

20. A steady state representation of breakpoint chlorination was found to be as adequate as a dynamic kinetic representation. However, neither approach was found to be truly satisfactory in explaining the complex reactions associated with breakpoint chlorination for waste stabilization lagoon effluent.

21. The mathematical model which was prepared to describe the disinfection of waste stabilization lagoon effluent was found to predict results which compare favorably with observed data for cases in which breakpoint chlorination does not apply. In comparing the predicted with the observed combined chlorine residual needed for a given coliform

reduction, 65 percent of the data sets produced correlation coefficients of significance at the 95 percent confidence level. For total and fecal coliforms, 81 percent of the data sets were significant at the 95 percent confidence level.

22. The results of this study indicate that, contrary to current opinions, adequate bacterial removal in waste stabilization ponds can be achieved with relatively low doses of applied chlorine during most of the year.

23. The performance of the lagoon system with respect to organic material, nutrients, and bacteria varied on a seasonal basis.

24. The summer period of lagoon coliform die-away or removal rate was approximately 16 times greater than the winter coliform die-away or removal rate.

25. Both the Most Probable Number (MPN) and Membrane Filter (MF) techniques for measuring total and fecal coliform bacteria appear to contain approximately the same amount of inherent variation.

26. The absolute numerical values of total and fecal coliform bacteria obtained by employing the Most Probable Number (MPN) and Membrane Filter (MF) techniques may differ substantially.

27. Both the Most Probable Number (MPN) and the Membrane Filter (MF) techniques identify similar trends in relative concentrations of total and fecal coliform bacteria through the lagoon system.

28. Disagreements between the absolute values of total and fecal coliform concentrations obtained using the Most Probable Number (MPN) and Membrane Filter (MF) techniques cannot be explained by either seasonal variations or the suspended solids concentrations of the sample.

29. Inherent variations in the Most Probable Number (MPN) and Membrane Filter (MF) techniques for measuring total and fecal coliform bacteria appear to be equivalent, and thus one technique does not appear to be more reliable than the other.

SECTION 3

RECOMMENDATIONS

1. Studies should be conducted to learn more about the chemical reactions and kinetics involved in breakpoint chlorination for wastewater high in nitrogenous materials such as waste stabilization lagoon effluent.

2. Studies are needed to improve the design of chlorine contact chambers with regard to minimizing the accumulation of solids. Although plug flow reactors are ideal for disinfection, they may also have limitations, depending on their design, because of problems associated with the accumulation and removal of solids.

3. Continued research is needed to determine other methods, besides intermittent sand filtration, for enhancing chlorination efficiency.

4. The effects of varying particle sizes for the intermittent sand filters with regards to improving chlorination efficiency should be determined as an aid in selecting appropriate sized sand for optimal improvement in efficiency.

5. Additional laboratory and field studies need to be conducted to determine more quantitatively and qualitatively the effects of chlorine on sulfide, suspended solids, chemical oxygen demand, and other lagoon effluent constituents.

6. Considering the variability of chlorination practice for lagoon effluent, economical studies should be conducted to determine the costs of chlorination compared with other alternatives.

7. Laboratory followed by field experimentation on the effects of specific chlorine residual species (monochloramine, dichloramine, hypochlorite ion, and hypochlorous acid) upon soluble chemical oxygen demand is needed. The effects of volatile suspended solids upon these specific species of chlorine residual would also be of interest for additional chlorine demand information.

8. Adaptations of the chlorine breakpoint curve should be evaluated where total organic nitrogen is of influence.

9. Studies should be undertaken which will indicate, specifically, if volatile suspended solids reductions seen during chlorination practices are the results of chlorination or the results of settling within the chlorine contact chambers.

10. Total and fecal coliform bacteria standards should be correlated with the technique (MPN or MF) employed to measure the bacterial concentrations.

SECTION 4

LITERATURE REVIEW

PERFORMANCE CHARACTERISTICS OF WASTE STABILIZATION LAGOONS

In investigating the effects of chlorination on waste stabilization lagoon effluent, it is necessary to gain a basic understanding of lagoon performance. Lagoons have been constructed following a wide variety of design parameters. Because of this, there is a large variance in the degree of treatment that can be expected from a lagoon system. Echelberger et al. (1971) found an effective reduction of fecal coliforms of only 90 percent, while Shindala and Mahloch (1974) described a reduction of both total and fecal coliforms in excess of 99 percent in multiple cell lagoon systems.

There are several reasons for differences in the degree of bacterial reduction among lagoon systems. Probably the most important single factor is the number and configuration of lagoon cells. Marais (1974) found that a multiple cell system is considerably more efficient than a single pond. It was also determined by Joshi, Parhad, and Rao (1973) that the reduction of *Salmonellae* is a function of the number and interconnection of lagoon cells. These factors were determined to be more important than detention time in producing effective bacterial reduction. However, Franzmathes (1970) indicated that careful control of detention time is of considerable importance for good lagoon performance. Another factor which may be of some importance in removing bacteria is the composition of the algae population. Although it has been shown that individual species have little effect on the die-off rate of enteric bacteria, it has also been shown by Burkhead (1973) that more rapid die-off rates occur when mixed cultures of algae are present.

The usual means of determining the effectiveness of a lagoon system is by measuring the reduction of fecal coliforms. However, the reduction of indicator organisms does not necessarily mean a corresponding reduction of pathogenic organisms. For example, it has been found by Davis and Gloyna (1972) that some *Salmonellae* actually grow quite well in algal laden lagoon waters. In spite of this shortcoming, Sobsey and Cooper (1973) have suggested that algal-bacterial systems are much more effective in reducing viruses than a bacterial system would be with no algae. There are a number of theories which attempt to describe the role of algae in reducing numbers of bacteria and viruses. Several of these are discussed by Parhad and Rao (1974) and include the ideas that algae produce anti-bacterial and other toxic substances, deplete the nutrients which would other wise be available for bacteria, produce a high pH, and cause microbial antagonism. Algal growth also establishes high oxidation-reduction potentials which adversely affect bacteria and viruses. The high pH produced by algae is especially important in controlling bacterial populations. For example, *Escherichia coli* cannot survive above a pH of 9.2. However, it is not uncommon for algae to produce pH values as high as 10.0 in a stabilization pond (Metcalf and Eddy, 1972).

Temperature also is an important factor in lagoon performance. It has been shown by Post (1970) that the disappearance of bacteria in stabilization ponds is directly related to water temperature. The water temperature is actually a function of air temperature and light intensity. As temperature increases, the rate of bacterial reduction also increases. In developing a relationship derived from the Arrhenius equation, Marais (1974) has pointed out that the rate of bacterial decay at a particular temperature, K_T, varies with temperature according to the following equation.

$$K_T = K_{20}\,\theta^{T-20^\circ C} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

In this equation, θ is a constant equal to 1.19 and K_{20}, the decay constant at 20°C, is 2.6.

Other factors, such as the aerobic-anaerobic nature of a lagoon, also influence bacterial removal efficiencies. An important concept, emphasized in the literature, is the idea that the degree of reduction of bacteria is highly variable from lagoon to lagoon, and even from season to season within the same lagoon. This suggests the need for a disinfection process to be used on lagoon effluent to ensure compliance with tightening water quality standards.

GENERAL PRINCIPLES OF CHLORINATION

Chlorination is the most widely accepted approach to disinfection of stabilization pond effluent. In determining the effects of chlorine on algal laden waters, it is necessary to review basic principles of chlorination. Most chlorination is accomplished by use of chlorine gas or by a hypochlorite, such as $Ca(OCl)_2$. When chlorine gas is used, the gas hydrolyzes in water to form hypochlorous acid (HOCl). In a pure water system, the reaction is as follows:

$$Cl_2 + H_2O \rightleftarrows HOCl + H^+ + Cl^- \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Hypochlorous acid dissociates to form OCl^- and H^+:

$$HOCl \rightleftarrows H^+ + OCl^- \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

When $Ca(OCl)_2$ is used, OCl^- is formed:

$$Ca(OCl)_2 \rightarrow Ca^{++} + 2OCl^- \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

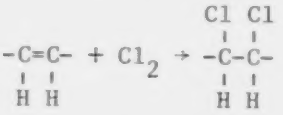
The OCl^- forms the same equilibrium conditions with HOCl as described by Equation 3. Chlorine in the form of HOCl and OCl^- is known as free chlorine.

To achieve efficient disinfection, it is generally desirable to have most of the free chlorine in the form of HOCl. According to Butterfield (1943), and more recently reinforced by Poduska and Hershey (1972) and Culp (1974), HOCl is much more effective as a disinfectant than OCl^-. Laubusch (1962) suggests that the reason for this is that OCl^- has more difficulty in penetrating bacterial cell walls because of its negative charge. Estimates indicate that for most bacteria, HOCl may be as much as 200 times more effective as a disinfectant than OCl^-. Scarpino et al. (1974) has found exception to this generalization and points out that OCl^- is more effective than HOCl against some animal viruses. Hypochlorous acid (HOCl) predominates at pH less than 5.0. As the pH increases, the equilibrium shifts towards the formation of OCl^-. In the pH range of 5.0-7.5, HOCl still accounts for 50 percent or more of the free chlorine. Above pH 7.5, OCl^- is the predominant form.

In many waters, particularly wastewaters, various chemical components react with free chlorine to form compounds which are ineffective as disinfectants (Snow, 1952). That is, the rates of reactions between chlorine and these components are faster than the rate at which chlorine attacks and kills bacteria and viruses. As pointed out by Sawyer (1960) Fe^{++}, Mn^{++}, NO_2^-, and $S^=$ are common reducing agents which readily neutralize chlorine to the harmless chloride ion. A typical reaction is as follows.

$$H_2S + 4Cl_2 + 4H_2O \rightarrow H_2SO_4 + 8HCl \quad \ldots\ldots\ldots\ldots \quad (5)$$

Organic compounds with unsaturated carbon linkages also react readily with chlorine. For example,



$$\underset{\mathrm{H}\ \ \mathrm{H}}{-\mathrm{C{=}C}-} + Cl_2 \rightarrow \overset{\mathrm{Cl}\ \ \mathrm{Cl}}{\underset{\mathrm{H}\ \ \mathrm{H}}{-\mathrm{C{-}C}-}} \quad \ldots\ldots\ldots\ldots \quad (6)$$

Chloro-substitution reactions may also occur.

Ammonia reacts with free chlorine, but the compounds formed are not entirely ineffective in killing bacteria and viruses. In fact, chloramines, as these compounds are known, are very important in disinfection because of their persistence in water and wastewater. Free chlorine is considerably more effective as a disinfectant than are chloramines. Butterfield and Wattie (1946) and Culp (1974) have pointed out that chloramines are only about 1/25th as effective in killing bacteria. Also, chloramines require a contact period of 60-144 times longer than the same concentration of free chlorine to produce the same kill. Chloramines are fairly stable and can continue to provide disinfection activity for some time after application. The common forms of chloramines, or combined chlorine as they are called, are monochloramine, dichloramine, and nitrogen trichloride. The reactions for their formation are as follows.

$$NH_3 + HOCl \rightleftarrows NH_2Cl + H_2O \quad \ldots\ldots\ldots\ldots \quad (7)$$

$$NH_2Cl + HOCl \rightleftarrows NHCl_2 + H_2O \quad \ldots\ldots\ldots\ldots \quad (8)$$

$$NHCl_2 + HOCl \rightleftarrows NCl_3 + H_2O \quad \ldots\ldots\ldots\ldots \quad (9)$$

Moore (1951) and Culp (1974) indicate that monochloramine predominates above pH 8.5, while dichloramine predominates in the range of pH 4.5 to pH 8.5. Below pH 4.5, nitrogen trichloride is the predominant form. The rates at which chloramines are formed are extremely rapid and are generally considered to follow second order reaction kinetics. For example, the reaction rate for monochloramine formation can be expressed by the following equation.

$$\frac{dC}{dt} = -K_r CN \quad . . . . \quad (10)$$

In this equation, dC/dt is the rate of decrease of HOCl or NH_3 per unit time, K_r is a rate constant, C is the concentration of hypochlorous acid in moles/l and N is the concentration of ammonia in moles/l. The rates of reactions are very much pH and temperature dependent as pointed out by Weil and Morris (1949) and Moore (1951). Jolley (1973) gave K_r for monochloramine formation a value of 6.11×10^6 l/mole-sec at 25°C. At this rate, monochloramine formation is 99 percent complete within one minute. The value of K_r for dichloramine formation was 3.4×10^2 l/mole-sec at 25°C. Nitrogen trichloride is formed more slowly than either monochloramine or dichloramine. The rate of formation of chloramines, particularly monochloramine, is faster, in fact, than the rate of inactivation of many types of bacteria. Culp (1974), however, has shown that chlorine does inactivate some viruses at an even faster rate than chloramine formation.

Chlorine can be used as a treatment step to drive off undesirable ammonia. This is known as breakpoint chlorination. In this process, chlorine is added until all the chlorine has reacted with ammonia to form combined chlorine (chloramines). With the addition of more chlorine, the ammonia is converted to nitrogen gas and driven off while chlorine is reduced to chloride ion. Any additional chlorine beyond the "breakpoint" is maintained in solution as free chlorine residual. The mechanisms involved in breakpoint chlorination are fairly complex, but the overall reaction may be represented as follows.

$$2NH_3 + 3HOCl \rightarrow N_2\uparrow + 3HCl + 3H_2O \quad . . . . \quad (11)$$

The weight ratio between chlorine and ammonia (Cl_2:NH_3-N) required to reach breakpoint has been found to vary between 7.6:1, by Stasiuk, Hetling, and Shuster (1974), and 10:1 by Culp (1974). Laubusch (1962) has pointed out that, theoretically, maximum chloramine formation occurs when the initial molar Cl_2:NH_3-N ratio is 1:1. Breakpoint occurs when that ratio is 2:1. Because of the large doses of chlorine required, particularly in the treatment of wastewater, breakpoint chlorination is seldom employed. When it is used, chlorine dosages greater than necessary to reach the breakpoint are common, thereby leaving an excess chlorine residual in the effluent.

In wastewater chlorination, the ideal breakpoint curve is seldom achieved. This is because of the high concentrations of organic nitrogen generally contained in wastewater. Although the mechanisms involved in breakpoint chlorination are fairly well defined for water-ammonia systems (Morris and Wei, 1969, Wei, 1972; and Wei and Morris, 1974), little is known about the mechanisms of breakpoint chlorination reactions in water containing large concentrations of organic nitrogen. A comparison between the ideal breakpoint curve expected in drinking water chlorination and a typical wastewater breakpoint curve is shown in Figure 1.

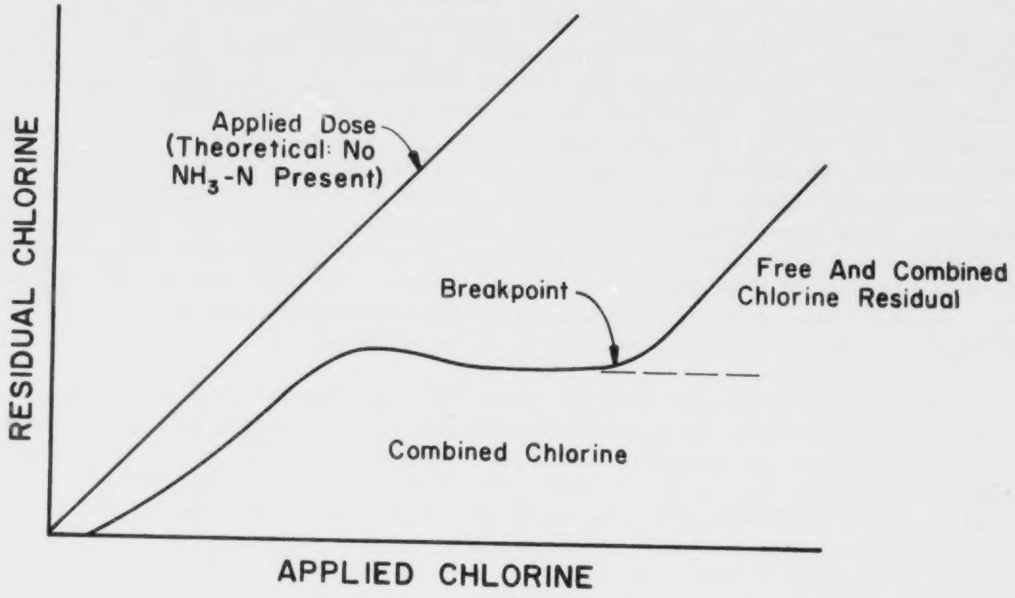
There are several ways of evaluating the effectiveness of chlorine as a disinfectant. The most obvious approach is to determine bacterial counts before and after chlorination. Since it is generally quite difficult to enumerate pathogenic bacteria and viruses, the indicator organisms of total and fecal coliforms are usually used to measure the effectiveness of disinfection. Fecal coliforms are particularly useful in indicating the possible presence of enteric pathogens. Although coliforms are extremely useful, an absence of coliforms does not necessarily guarantee the absence of pathogenic organisms. For example, Durham and Wolf (1973) have pointed out that viruses are not necessarily affected by chlorine in the same way as coliforms. Nevertheless, coliform counts are frequently used as a standard method of measuring disinfection efficiency.

The most common technique for enumerating coliforms in chlorinated water is the Most Probable Number (MPN) method described in Standard Methods (1971). The membrane filter (MF) method has also been used, although it has been pointed out by Hufham (1974) that the standard membrane filter technique is not recommended for enumerating fecal coliforms in chlorinated samples. New enrichment procedures have been developed as described by Rose, Geldreich, and Litsky (1975) and Lin (1973 and 1974) to improve the recovery of fecal coliforms in chlorinated samples. Initial investigations indicate a correlation between MPN and the enrichment MF procedures. However, sufficient data are not yet available to suggest the abandonment of the MPN method in favor of the MF enrichment procedure.

In conjunction with coliform enumeration, chlorine residual monitoring is an important tool in maintaining effective disinfection practice. Once the correlation between the desired final coliform density and chlorine residual at the end of a specified contact time has been established, continuous monitoring of that residual should ensure the proper chlorine dose necessary to achieve adequate disinfection at all times. Because of the importance of chlorine residual as a control tool, and also because an excess of chlorine residual may impose a toxic burden to the aquatic species in the receiving stream, it is important to select the most reliable method for measuring chlorine residual. Collins and Deaner (1973) recommend the use of the amperometric titration method. Chambers (1971) has found that amperometric chlorine residual is most closely related to virus disinfection and also recommends the use of that method.

Very little is known concerning the actual mechanisms by which chlorine kills viruses and bacteria. Many theories, however, have been proposed. As an example, Venkobachar, Iyengar, and Rao (1975) have postulated that the inhibitions of total dehydrogenase activity is correlated with the percent of bacterial kill. In *Escherichia*, it has been found that succinic dehydrogenase activity decreases markedly with bactericidal concentrations of chlorine.

Wastewater Breakpoint Curve



Ideal Breakpoint Curve

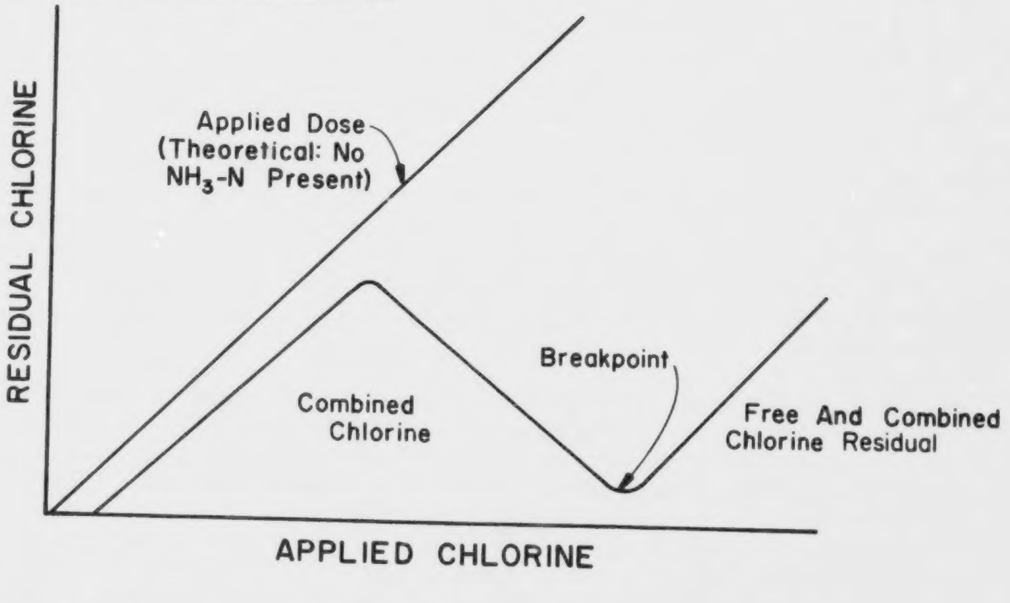


Figure 1. Comparison between ideal and wastewater breakpoint chlorination curves.

DISINFECTION OF ALGAE LADEN WATERS

For many years, chlorine has been used primarily as a disinfectant for drinking waters. However, with increasing emphasis on the quality of wastewater effluents, chlorination has gained considerable acceptance as a unit process in wastewater treatment for obtaining adequate bacterial reduction. The degree and rate of disinfection are highly dependent upon the characteristics of the wastewater. Since most wastewaters are relatively high in ammonia concentrations, disinfection is achieved almost entirely by combined chlorine. This means that long contact times are required to achieve the desired bacterial reduction. The age and composition of microorganisms also has some bearing on the degree of disinfection. It has been shown by Rabosky (1972) that young, actively metabolizing microorganisms are more easily destroyed by chlorination than are older cultures.

Other benefits may be derived from chlorination of wastewater besides disinfection. As well as oxidizing ammonia, as previously mentioned, chlorine may also be useful in lowering biochemical oxygen demand (BOD_5). Zaloum and Murphy (1974) observed a 40 percent reduction in BOD_5 and attributed the reduction to a long contact time with chlorine and to an unequal microbial concentration in their samples resulting from the presence of chloramines. However, they also found that chlorine had little or no effect on the ultimate BOD or BOD_5 once breakpoint chlorination was achieved. Another parameter of wastewater which is affected is the dissolved oxygen (DO). Silvey, Abshire, and Nunez (1974) observed an increase of DO in wastewater resulting from chlorination.

Although there are apparent advantages to using chlorine as a disinfectant for wastewater, there are also some questions concerning its value. Malone and Bailey (1969) have reported the results of several investigators which indicates that chlorination practice which is based solely on chlorine residual and chlorine contact time without regard to effluent coliform concentrations is ineffective and inefficient. Malone and Bailey (1969) argue that properly designed oxidation ponds may be a suitable substitute for chlorination. Probably one of the most important questions concerning the value of chlorine as a disinfectant is its ability to destroy pathogens as well as indicator organisms. Durham and Wolf (1973) have found that indigenous coliphages are more resistant to chlorine disinfection than coliforms. Evidence also indicates that pathogens are just as resistant to chlorine as coliphages. In fact, there is very little correlation between coliform and pathogen destruction (Durham and Wolf, 1973).

The chlorination of waste stabilization lagoon effluent is more complicated because of the presence of high concentrations of algae. Hom (1970) found that chlorination of algal laden waters was effective in producing a 99.8 percent reduction of coliforms. However, evidence indicates that the chlorine doses required to produce such a kill may have adverse effects on effluent quality. For example, White (1973) indicates that algae increase the chlorine demand. This, in turn, means higher initial doses of chlorine are required to produce the desired degree of disinfection. Echelberger et al. (1971) explained that the reason algae may increase the chlorine demand is that when high doses of chlorine are used, there is a possibility that algae cells are lysed and dissolved organic compounds released from inside the cells. This new source of organic material becomes another food source for microbial populations. Consequently, the BOD_5 of the treated effluent rises, as does the chlorine demand.

The amount of chlorine demand exerted by algae is highly variable. For example, Dinges and Rust (1969) found that the 20 minute chlorine demand of stabilization pond effluent was between 2.65-3.00 mg/l. Burkhead and O'Brien (1973) found that for lower levels of chlorine dose, there was very little destruction of algae cells and thus, little increased chlorine demand attributable to algae. However, for higher chlorine doses, destruction of algae cells and increases in BOD_5 were observed. Echelberger et al. (1971) suggest that the degree of cell destruction is somewhat dependent upon the particular algae species. They found a correlation between algal degradation and the surface area/volume ratio of particular algae species at a given chlorine dose. Kott (1971) found that the green alga *Chlorella* is one species of algae that shows a resistance to chlorine penetration. One example of the increase in BOD_5 due to disruption of algal cells by chlorine was reported by Hom (1972), who found that when 2.0 mg/l chlorine was applied to stabilization pond effluent, the BOD_5 measured was 20 mg/l. However, when 64 mg/l chlorine was used, the BOD_5 increased to 129 mg/l.

The use of chlorine on algal laden waters may not necessarily be accompanied by adverse effects. Dinges and Rust (1969) have pointed out that in some cases, chlorination of stabilization pond effluents may actually decrease the BOD_5. At the same time, it was found that DO either remained unchanged or increased slightly. Chlorine may also be used effectively to reduce suspended solids (SS). Kinman (1972) found that chlorine disinfection efficiency improves as SS concentration decreases. Echelberger et al. (1971) have pointed out that chlorine enhances the flocculation of algal masses. They also found that chlorine produces an immediate decrease in volatile suspended solids (VSS) (by 52.3%) and turbidity.

In examining the evidence, it appears that although chlorine can have serious adverse affects on algal laden waters, it is possible to achieve effective disinfection without the destruction of algae cells (Burkhead and O'Brien, 1973). Kinman (1972) reported that algae cells survived exposure to chlorine after one hour of contact time. Kott (1973) found that there was no destruction of algae cells when exposed to 0.4 mg/l residual chlorine for less than two hours. After two hours, the algae cell counts were found to decrease by 30 percent. Kott (1971) also suggests that regardless of the initial algae concentration, for a given chlorine dose, contact time is the most important factor in controlling the reduction of algae cells. In fact, he recommends that low initial doses, coupled with relatively long contact periods, is a better approach to disinfection than high chlorine doses for short periods of contact.

In examining the greater importance of contact time over chlorine dose, Kott (1971) found that most of the bacterial kill takes place within the first 30 minutes and that most of the chlorine demand occurs within the first five minutes of contact. Continued chlorine dissipation occurs at a rather slow rate. For contact periods greater than one-half hour to six hours, there is very little increase in the reduction of coliforms. This suggests that when chlorinating lagoon effluents, the initial chlorine dose should be as low as possible to produce effective bacterial kill within a contact period long enough for maximum disinfection efficiency and short enough to prevent the destruction of algal cell walls. Various combinations of chlorine doses, residuals, and contact times have been suggested for optimizing disinfection of stabilization lagoon effluents. For example, Kinman (1972) has suggested a chlorine dose sufficient to leave a residual of 1.0 mg/l after a minimum contact period of 10 minutes, and preferably 30 minutes. White (1973) found that initial doses of 20-30 mg/l produce optimum disinfection in 30-45 minutes with a remaining chlorine residual of 1-4 mg/l. Kott (1971) found that a dose of 8 mg/l was sufficient to attain the desired bacteriological effect within a contact period of 30 minutes. Of course, the operational parameters for successful chlorination depend on the effluent characteristics of each particular stabilization pond, as well as the season of the year.

Besides chlorine dose, residual, and contact time, additional factors must be taken into account in disinfecting algal laden waters. One factor is the toxicity of chlorinated hydrocarbons which are formed when chlorine is used on waters which are high in organic content. Brungs (1973) found chlorine and chlorinated compounds resulting from chlorination of wastewater to be highly toxic to fish and has suggested that chlorine residuals in receiving waters should not exceed 0.002 mg/l for protection of most aquatic organisms in areas where continuous chlorination occurs. Collins and Deaner (1973) have found that chlorine residuals of greater than 0.1 mg/l are toxic to fish. Zillich (1972) determined that chloramine concentrations of 0.06 to 0.08 mg/l are lethal to trout and that 0.16 to 0.21 mg/l are lethal to fathead minnows. Ward et al. (1976) found that sulfur dioxide dechlorination of chlorinated activated sludge effluent completely eliminated the toxic effects, both acute and chronic, of chlorine to various species of warm-water and cold-water fish.

DESIGN OF CHLORINATION FACILITIES

When designing facilities for the chlorination of wastewater, several special considerations must be taken into account. For one, the design of most chlorine contact tanks are based upon Chick's Law: $\ln (N/N_o) = -kt$ where N = the number of organisms surviving after a given time, t, and N_o = the numbers of organisms at time zero (Chick, 1908). The relationship holds fairly well for potable water treatment. However, the disinfection of wastewater does not always follow Chick's Law (Collin, Selleck, and White, 1971). This deviation is due to chloramines, bacterial clumping, adherence of bacteria to solids, and to consumption of chlorine residual by various chlorine demanding materials. As a result, either the time of exposure or the chlorine dose must be increased to produce the same bacterial kill in wastewater as in water.

Another problem associated with the design of contact tanks stems from the fact that most designs are based on theoretical detention time determined by dividing the tank volume by the flow rate. In practice Deaner (undated) has shown that actual detention times may vary between 30 and 80 percent of the theoretical detention times. Shorter residence times are caused by short circuiting and dead spaces and, as determined by Kothandaraman and Evans (1974), chlorination efficiency is reduced and solids accumulation increased. With a shorter contact time and extra chlorine demand exerted by the build up of solids, applied chlorine dosage must be increased to produce the desired degree of disinfection. Not only is this an inefficient use of the resource, but in addition operational costs rise markedly due to the higher chlorine demand and increased corrosion of equipment. Higher chlorine dose also promotes the increased likelihood of formation of undesirable chlorinated hydrocarbons discharged into the environment.

The short circuiting problem, and consequently the extreme variability of residence times, causes difficulty in maintaining prescribed levels of chlorine residual. The frequent attention of an operator is required to alter chlorine doses in maintaining constant chlorine residuals.

To provide adequate disinfection of wastewater, the basic approach to good contact tank design should include a thorough investigation of hydraulic characteristics of various designs and then the selection of design features which will optimize hydraulic performance. The important design considerations include optimization of mixing, contact time, and chlorine dose.

The hydraulic characteristics of a chlorine contact tank are generally determined by conducting tracer studies on flow patterns through the tank. Several possible tracers are available. Louie and Fohrman (1968) used conductivity to determine detention times in contact tanks. However, it is often difficult to handle the large amounts of salt generally required for such studies. Radioactive tracers are another possibility. However, these are almost never used because of the potential hazard of disposal.

Perhaps the most useful tracers are fluorescent dyes. Most of them are rather inexpensive and easy to obtain. Two of the dyes commonly used in contact tank tracer studies are Rhodamine WT, used by Hart, Allen, and Dzialo (1975), and Rhodamine B, recommended by Deaner (undated) and Kothandaraman and Evans (1974). Other fluorescent dyes are also available but Rhodamine dyes have the advantages of being detectable at low concentrations and having low sorption tendencies.

Tracer studies to evaluate the flow characteristics of the contact tank may be conducted in several ways. Three methods have been suggested by Sawyer (1967). These include conventional, statistical, and dynamic analysis. Conventional and statistical analyses are the most commonly used.

The conventional method of analysis consists of selecting specific values from the dispersion flow curve and using these as indices to describe the performance characteristics of a tank. Marske and Boyle (1973) and Hart, Allen, and Dzialo (1975) have described the points and indices commonly used as follows.

T = Q/V (theoretical detention time)
t_i = time for tracer to initially appear at tank outlet
t_p = time for tracer at outlet to reach peak concentration

t_{10}, t_{50}, t_{90} = time for 10, 50, and 90 percent of the tracer to pass at tank outlet
t_g = time to reach centroid of the effluent curve
t_i/T = index of short circuiting
t_p/T = index of modal detention time
t_{50}/T = index of mean detention time
t_g/T = index of average detention time
t_{90}/t_{10} = Morrill Dispersion Index-indication of degree of mixing

In constructing dispersion flow curves, it is common practice to use dimensionless expressions for tracer concentrations and times. This is done to facilitate comparisons of hydraulic performance between tanks where different tracer concentration and detention times are involved. The dimensionless dispersion flow curve is obtained by plotting C/C_o against t/T where C is the tracer concentration at any time t, C_o is the initial tracer concentration, and T is the theoretical detention time (Q/V). A typical dispersion flow plot is represented in Figure 2.

The parameter which is probably the most useful in accurately describing hydraulic performance is the Morrill Index (MI). As MI approaches 1.0, the flow through the tank approaches ideal plug flow. The larger MI becomes, the more closely the flow in the tank approaches backmix reactor conditions. The two extreme flow conditions are displayed in Figure 3.

There are several different statistical approaches used to evaluate hydraulic performance. One approach, which has gained widespread acceptance, describes the flow regime of a basin in terms of plug flow and perfect mixing. It also uses descriptive parameters to define effective space and dead space. This method is discussed in some detail by Marske and Boyle (1973) and by Wolf and Resnick (1963). A variation of this approach uses the entire tracer curve to describe hydraulic efficiency in terms of a function of time, F(t), and is explained in detail by Rebhum and Argaman (1965) and by Deaner (1970). The function F(t) is calculated from the following equation.

$$\text{Log}\,[1 - F(t)] = [-\text{Log}\,e/(1 - p)\ (1 - m)][t/T - p(1 - m)] \quad \ldots\ldots\ldots\ldots \quad (12)$$

In this equation, m = dead space fraction, 1 - m = effective fraction, p = plug flow fraction, 1 - p = perfect mixing fraction, t = any time corresponding to the time used to get F(t), and T = theoretical detention time.

Probably the most widely used statistical approach is the chemical engineering dispersion index, recommended by Marske and Boyle (1973). It is considered to be extremely reliable, since it is calculated using the entire dispersion flow curve. The dispersion index, d, is calculated from the following equation.

$$d = \frac{\left(\frac{\Sigma t^2 C}{\Sigma C}\right) - \left(\frac{\Sigma t C}{\Sigma C}\right)^2}{\left(\frac{\Sigma t C}{\Sigma C}\right)^2} \quad \ldots\ldots\ldots\ldots\ldots \quad (13)$$

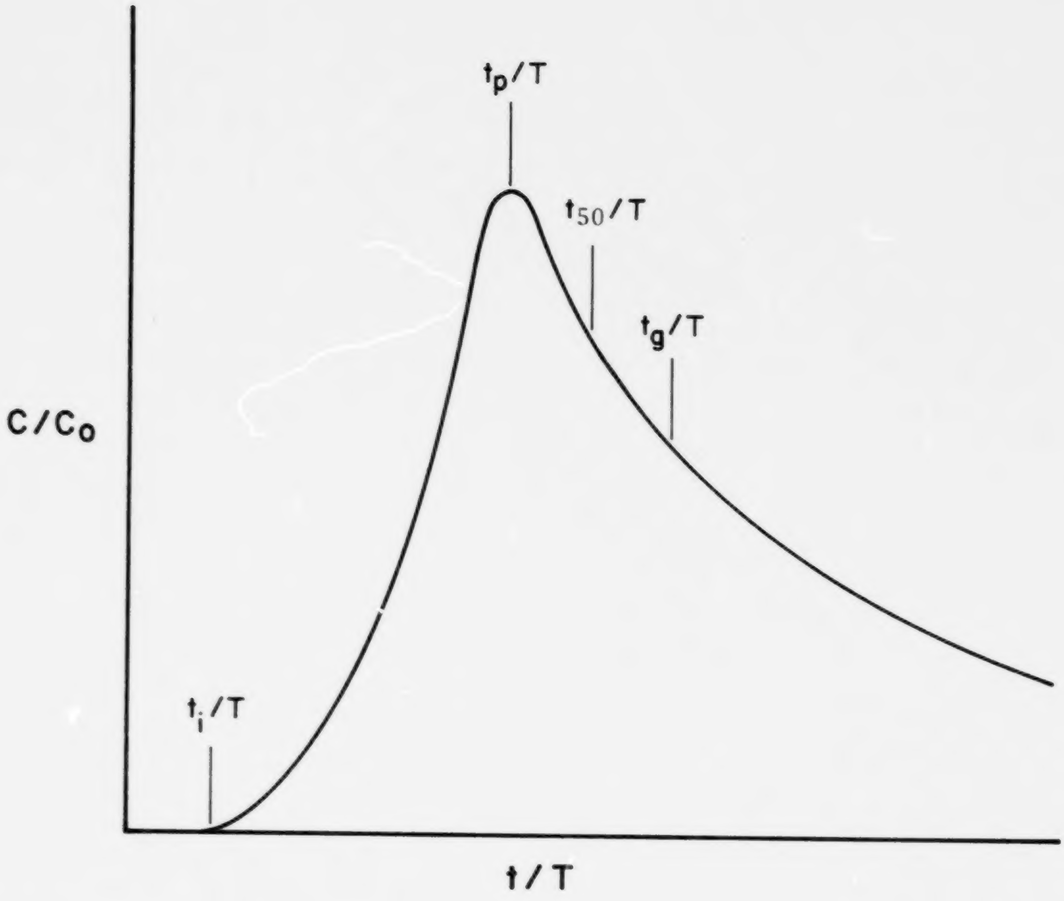


Figure 2. Typical dispersion flow curve.

In this equation, C is the tracer concentration at any time, t.

The dispersion index has the strongest statistical probability of correctly describing the hydraulic performance because it includes all points on the dispersion flow curve. Conventional parameters only use one, or at the best, only a portion of the curve. In comparing the dispersion index with conventional parameters, it has been found that the Morrill Index is closely related to the dispersion index and can be considered as the most reliable conventional parameter in accurately describing the hydraulic performance of a tank. According to Marske and Boyle (1973), the least reliable indicators of flow characteristics are considered to be the percent of effective space, t_{50}/T, and t_i/T.

In good chlorine contact tank design, the hydraulic characteristics facilitate a minimum usage of chlorine with a maximum exposure of microorganisms to the chlorine. An evaluation of a number of wastewater chlorine

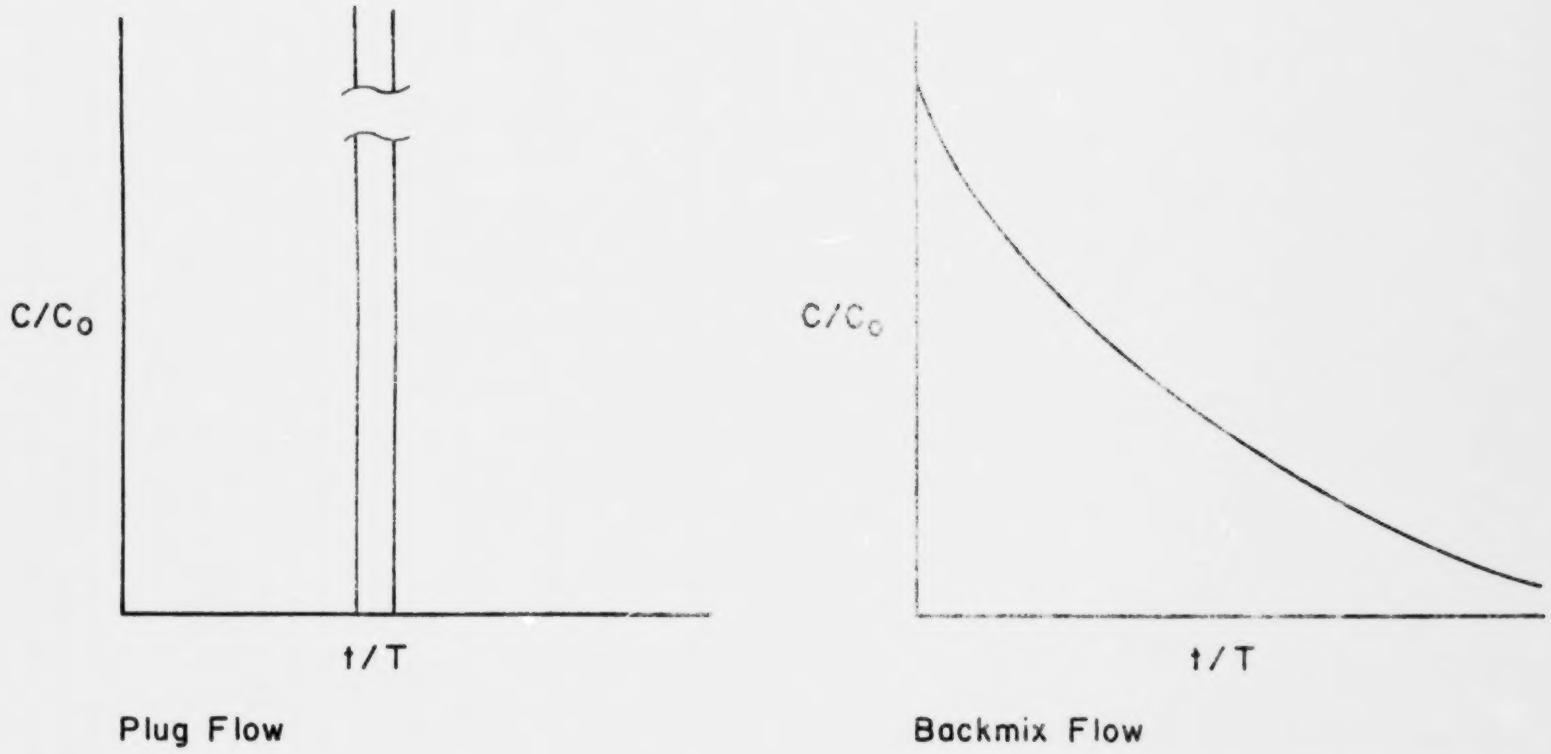


Figure 3. Comparison of plug and backmix flow.

contact tanks indicates that mixing, detention time, and chlorine dosage are the critical factors in providing adequate disinfection. According to Hart, Allen, and Dzialo (1975), good contact tank design not only optimizes disinfection efficiency, but should also minimize the concentration of undesirable compounds being discharged to the environment and reduce the accumulation of solids in the tank by keeping the flow-through velocity high enough to prevent solids from settling.

Kothandaraman and Evans (1974) consider initial mixing as one of the most important considerations for good disinfection. This is because most disinfection takes place within the first few minutes of contact. Initial mixing provides a uniform contact of chlorine with microorganisms and also prevents chlorine stratification in the contact tank. Mixing can be accomplished either by applying the chlorine solution to the wastewater in a pressure conduit under highly turbulent conditions or by means of a mechanical mixer. Collins, Selleck, and White (1971) consider the turbulent reactor as the most effective in producing maximal bacterial kill in the shortest contact time. It has been found that a contact time of 6 to 18 seconds is generally sufficient in a turbulent reactor. If a mechanical mixer is used, the chlorine solution should be added to the wastewater immediately upstream from the mixer. The common practice is to use a portion of the wastewater stream for solution water. When this is done, most of the chlorine is in the combined form before the solution line is ever mixed with the mainstream of wastewater. However, this practice apparently has little affect on the efficiency of the wastewater chlorination process. Another form of mixing which has been found to be effective by Louie and Fohrman (1968), is the use of a hydraulic jump in combination with over and under baffles. Both the turbulent reactor and the baffle system of mixing offer the advantage of reducing operation and maintenance costs over those for the mechanical mixer.

Rapid mixing is followed by flow of the chlorinated wastewater into the contact tank. Most approaches to good contact tank design are based on the idea that plug flow is the most desirable hydraulic performance characteristic to achieve in producing efficient disinfection. Plug flow decreases short circuiting, dead spaces, spiraling, and eddy currents and also closes the gap between theoretical and actual detention times. However, not all designs are based upon plug flow reactors. Kokoropoulos (1973) has suggested the use of a series of backmix reactors to improve chlorination efficiency. In this approach, the tank shapes are not important as long as stratification and short circuiting are eliminated. One advantage to this approach is the ease with which treatment capacity could be increased by just adding another reactor. However, high initial and operational costs could offset this advantage.

For the design of tanks in which plug flow is the objective, tank shape is an important consideration. Kothandaraman and Evans (1972) have indicated that a long, narrow, straight contact chamber would be the most desirable shape in achieving plug flow. However, because of cost and space limitations, this approach is generally not practicable. Circular shapes have also been used, but Warwick (1968) found that generally these tanks do not perform efficiently with respect to hydraulic characteristics. Most tanks are based on a rectangular shape, which generally is the most practical design.

Conventional design practices can be enhanced by paying particular attention to inflow and outflow structures. They should be designed in such a fashion as to distribute wastewater flow uniformly across the tank cross-section. One of the most effective designs is that of a sharpcrested weir covering the width of the contact tank at the inlet and outlet, according to Marske and Boyle (1973). This design minimizes the weir overflow rate and greatly enhances hydraulic characteristics through the tank.

A common practice for improving plug flow conditions in a contact tank involves the use of baffles. Longitudinal baffles are generally more effective than cross baffles. In a study of seven different types of chlorine contact tank configurations by Marske and Boyle (1973), it was found that the longitudinally baffled serpentine flow and the flow resulting in an annular ring around a secondary clarifier were the best configurations for approaching plug flow. Both have the effect of increasing the ratio of length to width (L/W) of the contact tank. The L/W ratio is often considered to be the most important design consideration for chlorine contact tanks. Marske and Boyle (1973) recommend a minimum L/W ratio of 40:1. Baffles have also been used effectively across the cross section of a tank. Kothandaraman and Evans (1974) found that hydraulic performance has been improved by placing baffles near the inlet end of tanks to suppress the kinetic energy of incoming jets.

Simple baffles per se are often not sufficient to produce the desired hydraulic characteristics. Stephenson and Lauderbaugh (1971) have found that hammerhead shapes at baffle tips are effective in reducing short circuiting and flow separation. Corner fillers have also been found to eliminate dead spaces and thus, decrease the build up of solids in corners. These fillers, however, seem to have little effect on flow characteristics. In some cases, directional vanes around the ends of baffles have been found to produce lower head losses and more uniform flow through the contact tank.

Another approach to improving the effectiveness of chlorine contact tanks has involved aeration. Kothandaraman and Evans (1974) found that mild agitation with compressed air improves hydraulic characteristics and may improve bacterial kill by providing closer contact of microorganisms with residual chlorine. This method also reduces solids accumulation and thus decreases chlorine demand caused by putrefication of settled solids. Using this approach in a field evaluation, it was found that adequate bacterial kill can be obtained in secondary wastewater with a dose of 2-3 mg/l chlorine and a contact time of only 15 minutes. Fifteen minutes should be considered as the minimum residence time for chlorine contact tanks (Kothandaraman and Evans, 1974). If the accumulation of solids is not adequately prevented by aeration, it is recommended (Kothandaraman and Evans, 1974) that they be removed at least once a day by some mechanical or other means in order to keep chlorine demand as low as possible.

Another design parameter to be considered is that of depth. In very shallow contact tanks, it is possible for air currents to cause short circuiting. However, this is generally not a significant problem in tanks designed with standard depths.

When considering upgrading existing chlorine contact tanks, it is generally not possible to completely redesign the tank. However Hart, Allen, and Dzialo (1975) have suggested several ways practical improvements can be made in flow characteristics. Gates added to screen and sludge notches have been found to reduce short circuiting. Spiraling flow patterns have been eliminated by circular baffle plates placed at tank inlets. Additional improvements can be made by using directional vanes to direct flow in a more uniform fashion and by using stop baffles with curved vanes to reduce eddying. In one example, these improvements reduced short circuiting by 80 percent in an existing contact tank (Hart, Allen, and Dzialo, 1975). Stephenson and Lauderbaugh (1971) have suggested the use of pre-cast baffles. These can be installed with minimum down time. Although it is more efficient to use longitudinal baffles, cross baffles may be more economical to construct. It has been demonstrated that baffles installed in a maze configuration improved performance sufficiently to make economical factors more important in choosing a design than efficiency considerations.

CHLORINATION DYNAMICS

Most mathematical models describing the kinetics of disinfection account only for the dependent variables of bacterial density, chlorine concentration, and time. One of the earliest relationships for describing the rate of bacterial reduction due to chlorination was developed by Chick (1908) and has become known as Chick's Law. It states,

$$\text{Log } N_o - \text{Log } N = kt \quad \ldots \ldots \ldots \ldots \quad (14)$$

In this relationship, N_o = the initial number of organisms, N = the number of organisms after time, t, and k is a temperature dependent rate constant.

Chick's Law is commonly used for wastewater chlorination, although McKee, Brokaw, and McLaughlin (1960) have found that Chick's Law is not necessarily applicable to wastewater. They have proposed the following relationship.

$$\frac{N_t}{N_a} = \left(\frac{t}{a}\right)^m \quad \ldots \ldots \ldots \ldots \quad (15)$$

In this equation, N_t = the number of organisms at t minutes, N_a = the number of organisms at a minutes and m = slope on a log-log plot. The slope m has been found to vary between -0.08 to -0.38. They also developed the following relationship between coliform concentration and chlorine dosage.

$$\frac{1}{\log N} = 0.10 + 0.94x \quad \ldots \ldots \ldots \ldots \quad (16)$$

In Equation 16, x is the chlorine dosage in milliequivalents per liter and N is the coliform MPN. Chlorine dose is used instead of chlorine residual because the reactions take place so rapidly in wastewater that 99 percent of disinfection takes place before any residual can be measured.

A variation of this approach is discussed by Eliassen and Krieger (1950):

$$\text{Log } N = \frac{1}{a + bR} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

In this equation, N = coliform MPN, R = chlorine residual, and a and b are constants which are functions of the contact time and wastewater characteristics. Kokoropoulos (1973) defines a as the MPN coliform number when there is no chlorine residual in the tank and b as the rate of bacterial destruction.

Another relationship, proposed by Fair et al. (1948), is more applicable to water treatment than to wastewater treatment. It states,

$$C^n t = k \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

where C is the concentration of chlorine, t = contact time to produce a certain percent of kill, and n = a coefficient of dilution. Hom (1972) applied Equation 18 to the chlorination of oxidation pond effluent. He found that if $n > 1.0$, chlorine concentration is more important than contact time. For $n < 1.0$, the contact time has the greater effect on chlorination efficiency. And for $n = 1.0$, chlorine concentration and contact time are of equal importance in attaining the desired coliform kill. According to Moore (1951), $n = 1.0$ is the most common value of n, although values of n may vary from 0.75 to 2.0. Hom (1970) has suggested that when HOCl is the disinfectant species, n values vary from 0.67 to 1.6. When chlorine is in the form of $NHCl_2$, n varies from 0.75 to 1.0. Weber (1972) uses values of $n = 0.86$ and $k = 0.24$ for a 99 percent kill in time t and C in the form of free chlorine.

Fair et al. (1948) have proposed the following relationship to describe the amount of free chlorine necessary to produce a certain percent of bacterial kill in a specified time and as a function of pH.

$$R = A \frac{\left(1 + \frac{K}{[H^+]}\right)}{\left(1 + B \frac{K}{[H^+]}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

R is the total residual chlorine, A is the concentration of HOCl required to produce the desired kill, and B is the disinfection efficiency of OCl^- compared with HOCl. The B value is approximately equal to 1/80. K is the ionization constant between HOCl and H^+. This equation has some application to wastewater chlorination, although its most useful application is in drinking water chlorination.

A relationship which Hom (1972) has used to describe the bacterial die-off resulting from chlorination of algal laden waters is as follows.

$$\frac{dN}{dt} = -KNt^m C^n \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

Here, dN/dt is the number of organisms killed per unit time, K is a rate constant, t is time, m is a time or rate kill constant, C is the concentration of disinfectant, n is a dilution coefficient, and N is the number of bacteria in the water. When m and n are equal to zero, this equation reduces to Chick's Law.

Reid and Carlson (1974) applied Equation 20 to low temperature water and eliminated the variable n by solving for C^n in Equation 18 and substituting into Equation 20 to get the following.

$$\frac{dN}{dt} = -K'Nt^{m-1} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (21)$$

K' = kK in this equation. In linear form, this equation is expressed as follows.

$$\text{Log} \left(\text{Log} \frac{N}{N_o} \right) = \text{Log} \left(\frac{-K'}{m} \right) \; t^m \; \text{Log} \; t \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (22)$$

The slope of the line is m.

Another form of this equation presented by Hom (1972) applies when m = 0, but n ≠ 0.

$$\text{Log} \frac{N}{N_o} = -K_n \; \text{Log} \frac{t}{t_o} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (23)$$

This relationship was found to apply for chlorine residuals of 0.25-2.0 mg/l. The reaction rate constant for the n order reaction, $-K_n$, was found to vary between -2.2 and -3.4 for chlorinated pond effluents.

Selleck (1970) and Collins, Selleck, and White (1971) describe another relationship for determining bacterial reduction resulting from wastewater chlorination. Bacterial die-off is a function of chlorine residual and contact time.

$$y = y_o \, [1 + 0.23ct]^{-3} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (24)$$

Here, y is the coliform count at time t, y_o is the coliform count at t = 0, and c is the amperometric chlorine residual. A similar type of equation is also used to show that the type of mixing affects disinfection rates.

Selleck (1970) has used several equations to describe bacterial die-off for various combinations of flow and mixing characteristics. Collins, Selleck, and Saunier (1976) have also described differences in process efficiency as functions of flow characteristics. For example, the disinfection efficiency in a plug flow reactor is described in the following manner:

$$\frac{dy}{d(Ct)} = -ky \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (25)$$

C is the chlorine residual, t is the contact time, y is the density of coliform organisms, and k is a time dependent constant. An important point derived from these equations is that the mathematical representations of the action of chlorine on bacteria becomes more complex as flow characteristics deviate from plug flow.

An additional equation, although not dealing with the chlorination of wastewater, is worth mentioning. Klock (1971) used this equation to describe the die-off of coliforms in a waste stabilization lagoon as a function of energy terms. A similar approach may have application in wastewater chlorination. The equation is as follows.

$$\ln k = \frac{-E}{RT} + A \quad . . . . \quad (26)$$

In this equation, k is the coliform survival rate, E is the activation energy, R is the gas constant, T is absolute temperature, and A is a constant which is a function of pH and the oxidation potential.

Since very little is known about the actual mechanism of chlorination on bacteria, it is noted that mathematical representations are largely empirical. This is the simplest and most direct approach, especially since sufficient knowledge is unavailable for using simulation techniques. However, a serious disadvantage of empirical approaches is that constants are generally applicable only for the system from which they were developed. Generally, new constants must be developed each time the relationship is applied to a new system.

Although most of the emphasis has been placed on the development of relationships to describe the effect of chlorine on bacteria, it is also important to determine the mathematical relationships between chlorine and other water quality characteristics of lagoon effluent. One of the most important relationships needing development is the determination of the chlorine demand exerted by a particular wastewater.

Lin and Evans (1974) have used the following expression to determine chlorine demand.

$$\text{Demand (mg/l)} = Kt^n \quad . . . . \quad (27)$$

For this equation, t is the time in hours, and K and n are regression coefficients which are functions of the chlorine dose to NH_3-N weight ratios. One way of expressing these coefficients would be:

$$\begin{aligned} K &= K_1 \left(\frac{Cl}{NH_3\text{-}N}\right)^{K_2} \\ & \qquad\qquad . . . . \quad (28) \\ n &= n_1 \left(\frac{Cl}{NH_3\text{-}N}\right)^{n_2} \end{aligned}$$

Here, K_1, K_2, n_1, and n_2 are regression coefficients. Nitrogen, chemical oxygen demand (COD), and suspended solids (SS) were found to exert most of the chlorine demand.

Another relationship for indirectly determining chlorine demand was proposed by Hom (1970) and is based on residual chlorine.

$$R^n t = k \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

R is the residual chlorine, t is the time of reaction, n is the dilution coefficient for 90 to 99.999 percent removal of bacteria, and k is a rate constant. In this case, n was found to be 0.66 and k was found to be 1.16.

McKee, Brokaw and McLaughlin (1960) have made reference to the following relationship for determining chlorine demand.

$$\frac{D_t}{D_1} = t^{0.18-(0.17 \log D_1)} \quad \ldots\ldots\ldots\ldots\ldots \quad (30)$$

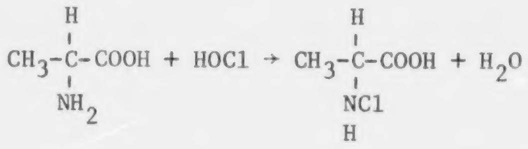
D_t is the chlorine demand at t hours and D_1 is the chlorine demand after one hour.

An approach based on predicting the chlorine residual given an initial dose is discussed by Selleck (1970) and Deaner (1973). The equation used is:

$$C = C_o - kt \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

For this relationship C is the chlorine residual at time t, C_o is the initial chlorine dose, and K is a constant, determined to be 7.1×10^{-3}/min for one particular batch chlorination study.

Mathematical relationships describing the interactions between chlorine and other wastewater constituents are generally unavailable. However, information on the basic changes which may occur in the major wastewater quality characteristics as a result of chlorination is important in developing optimum design chlorination systems for lagoon effluent. In discussing the effect of chlorine on solids, Holm (1973) found that chlorination of wastewater increases suspended solids (SS). Lin and Evans (1974) also found that SS are affected by chlorine. Irgens and Day (1966) used chlorination, in conjunction with sedimentation, to reduce volatile suspended solids (VSS) in wastewater by 81.6 percent. White (1972) observed that in algal laden waters, chlorine reduced SS by causing algae cells to clump together and settle out. Murphy, Zaloum, and Fulford (1975) found that chlorine oxidizes VSS in wastewater. McKee, Brokaw, and McLaughlin (1960) suggest that chlorine reacts with amino acids in VSS to form chlorinated hydrocarbons. An example of such a reaction might be as follows.



$$CH_3-\overset{H}{\underset{NH_2}{C}}-COOH + HOCl \rightarrow CH_3-\overset{H}{\underset{\underset{H}{NCl}}{C}}-COOH + H_2O \quad \ldots\ldots\ldots \quad (32)$$

Bewtra (1968) determined that there is no correlation between algal cell concentration, as measured by VSS, and chlorine demand. This indicates problems in trying to predict how much VSS will be reduced, given an initial VSS and chlorine dose.

The effects of chlorine on oxygen demand have been largely left undefined. This is particularly true for algal laden waters. Holm (1973) found that chlorine reduces biochemical oxygen demand (BOD_5) but has no affect on total organic carbon (TOC). Silvey, Abshire, and Nunez (1974) also observed reductions of BOD_5 in wastewater. Zaloum and Murphy (1974) observed initial reductions of BOD_5 but after long contact periods, BOD_5 increased. It was also determined that there was no change in total chemical oxygen demand (COD) or TOC before and after chlorination for doses up to 25 mg/l. Lin and Evans (1974) determined that chlorine residual does have an effect on COD but did not define the effect. Irgens and Day (1966) observed a reduction of COD by 71 percent by using chlorination in conjunction with settling. It is suspected that in the latter case, chlorine performed as a flocculent aid and that most of the COD was removed by sedimentation. Hom (1972) found that in algae laden waters, BOD_5 was increased at chlorine doses above 2 mg/l and for certain contact periods at lower doses. As the contact time was increased further, BOD_5 was observed to decrease. It was theorized that given sufficient contact time or high enough dose, chlorine causes the release of organic material within the algal cell causing the BOD_5 to increase. As the contact time is increased, the chlorine oxidizes the released organics and causes the BOD_5 to decrease again. Moore (1951) found that in wastewater a 1 mg/l uptake of chlorine generally corresponds to a 2 mg/l reduction of BOD_5.

Temperature has been found to have significant effects on the chlorination efficiency of wastewater. Fair et al. (1948) have used the Arrhenius equation to describe the relationship between temperature and length of time to produce a certain percent of bacterial kill:

$$\log \frac{t_1}{t_2} = \frac{E(T_2 - T_1)}{4.575\ T_1 T_2} \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (33)$$

T_1 and T_2 are temperatures in ^oK, t_1 and t_2 are the times required for a certain percent of bacterial kill at a fixed concentration of disinfectant, and E is the activation energy. Butterfield (1948) and Rabosky (1972) observed that less chlorine is required at higher temperatures to produce the same degree of kill observed at lower temperatures. White (1972) found that for cold winter temperatures, the contact time may have to be increased by as much as five times the summer contact time to produce the same disinfection with a given dose of chlorine. Reid and Carlson (1974) indicate that a 10°C rise in temperature doubles the reaction rate of disinfection.

The pH is also an important factor contributing to the efficient chlorination of wastewater. Culp (1974) has suggested that for ideal chlorination efficiency the pH should be near 7.5 for water containing NH_3-N and less than 7.0 for ammonia-free water. It has been observed by Klock (1971), Butterfield (1948), and Rabosky (1972) that high pH in stabilization pond effluent or other wastewater decreases chlorination efficiency. Therefore, at higher pH values, more chlorine is required to provide adequate disinfection.

Two final parameters affecting or being affected by chlorination are dissolved oxygen (DO) and ammonia-nitrogen (NH_3-N). DO has little affect on chlorination efficiency. However, Silvey, Abshire, and Nunez (1974) have found that chlorination may actually increase DO. NH_3-N is very important in affecting wastewater chlorination as previously discussed. The formation of chloramines greatly affects the rate and extent of disinfection. Chlorine also removes NH_3-N. The amount of chlorine required to reach breakpoint and thus, remove almost all of the ammonia is fairly well understood. Culp (1974) and White (1972) indicate that 10 mg of chlorine are required to remove 1 mg of NH_3-N. A slightly different figure of 7.6 mg chlorine for 1 mg NH_3-N is suggested by Stasiuk, Hetling, and Shuster (1974).

MATHEMATICAL MODELING APPROACHES

The literature indicates that very little has been done towards developing an overall mathematical model for optimizing chlorine doses and contact times for wastewater chlorination. This is especially true for chlorination of algae laden waters. Part of the reason for the latter is the lack of sufficient data on chlorination of algae laden waters. Also, a lack of quantitative information or interactions between chlorine and wastewater constituents has hindered the modeling approach.

For optimizing the chlorination of water supplies, Kuo and Jurs (1973) have developed a model based on a pattern vector of the form $X = (x_1, x_2, x_3 \ldots)$ to make decisions. The water quality data in the vector were normalized to improve pattern classifications. A "weight" vector, w, was used in conjunction with the pattern vector to produce a decision surface, $S=w \cdot X$. From the decision surface, optimal dosages were selected. From this model, it was determined that there is a positive correlation between chlorine dose, alkalinity, and NH_3-N. A negative correlation was determined for DO and temperature.

Another model for optimizing chlorination practices has been developed by Tikhe (1976). The objective of this model is to minimize construction and operational costs of chlorination facilities, while providing for adequate disinfection. Optimal design is selected on the basis of solutions to a differential equation which describes changes in the total cost with respect to changes in chlorine dose required to produce the desired level of disinfection. Johnson (1975) discusses another mathematical approach to optimizing disinfection. This approach is based upon a Poisson distribution to maximize pathogen inactivation. The chlorine dose required is dependent upon the initial concentration of organisms.

A mathematical modeling approach for application to wastewater chlorination has been developed by Stenstrom (1975). This approach uses dynamic solution techniques to describe the disinfection process in both batch and continuous flow reactors. Breakpoint kinetics, as described by Weil and Morris (1949), Morris and Wei (1969), Wei (1972), and Wei and Morris (1974), were used to develop the differential equations which describe the interactions between free and combined chlorine, ammonia, BOD_5, and bacteria. The model is restricted in application to wastewater which has been previously treated. It is also limited by the fact that breakpoint kinetics, as presently understood, are not necessarily applicable to wastewater containing high organic nitrogen concentrations.

SECTION 5

METHOD OF PROCEDURE

EXPERIMENTAL CHLORINATION FACILITIES

The Logan City wastewater stabilization lagoons were selected as the site for this study. These waste stabilization lagoons are located approximately two miles west of Logan, Utah. The lagoon system is composed of seven cells arranged in the configuration shown in Figure 4. Cells A_1 and A_2 are referred to as "primary cells," cells B_1 and B_2 are referred to as "secondary cells," and cells C, D, and E are referred to as "tertiary cells." A description of the surface areas, volumes, and effective depths for each cell is contained in Table 1. Under normal operating conditions, the lagoons have been found to be very effective in removing bacteria. During summer months, groundwater infiltration and irrigation return flow dilute the raw wastewater coming into the lagoons. Because of the dilute nature of the influent, it is possible to reduce the detention time in the lagoon system to well below that of the design residence time and still achieve satisfactory bacterial removal. During winter months, colder temperatures require that longer residence times be maintained in the lagoon system to provide adequate treatment. It is possible to increase the residence time in the system during this period because of reduced influent flows. In late fall, lagoon cells are drawn down and flows reduced from cell to cell. For several months during the winter, discharge of effluent is almost completely eliminated from the last cell (cell E).

Because of the relatively high bacteriological quality of the final lagoon effluent, it was initially determined that secondary cell effluent (cell B_1) should be used for this chlorination study. Later, it was found that primary effluent (i.e., from cell A_1 or A_2) would provide greater coliform concentrations and meaning to the data, at least in the winter months, and, therefore, provisions were made to chlorinate effluent from cell A_2. When secondary effluent (cell B_1) was used, it was drawn by gravity from cell B_1 into a sump beneath the main pump house. When primary effluent (cell A_2) was used, it was pumped from cell A_2 through more than 4000 feet of four inch PVC pipe to the sump. The overall experimental arrangement for chlorinating either secondary or primary effluent is shown in Figure 5.

One of the major objectives of the project was to determine the effect algae have on chlorination of lagoon effluents. Therefore, provisions were made to filter a portion of the secondary or primary effluent through intermittent sand filters which were previously constructed for other experiments at the Logan City lagoons. The filtered effluent was collected in a concrete trough and then pumped to two 45.5 m^3 (12,000 gallon) capacity storage tanks

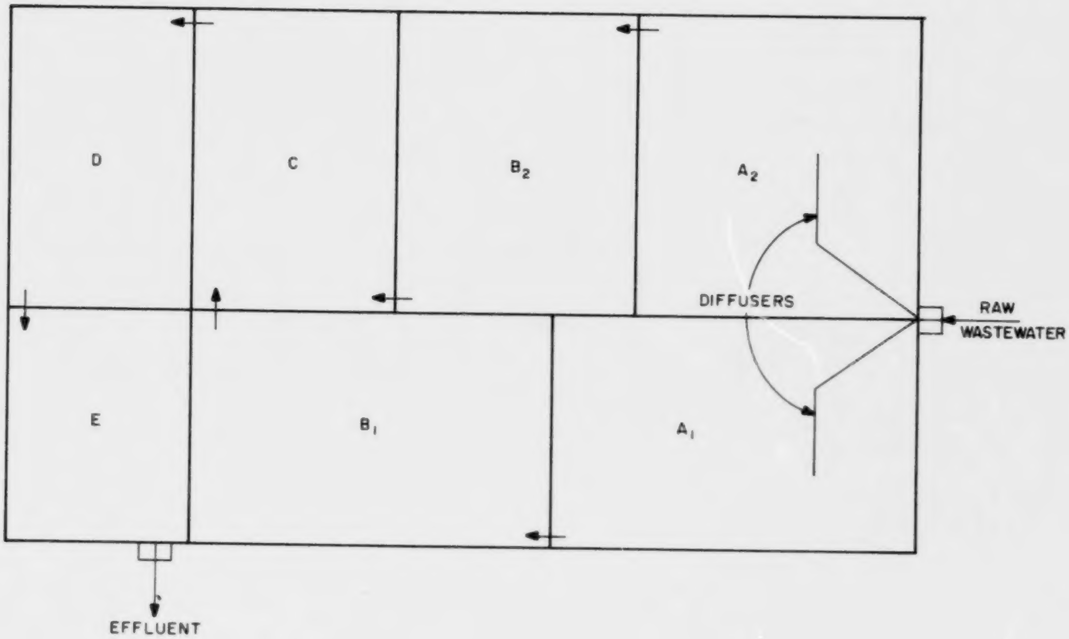


Figure 4. Flow diagram of Logan City Wastewater Lagoon System.

TABLE 1. DESCRIPTION OF LOGAN CITY WASTEWATER LAGOONS

Cell	Water Surface Area (Hectares)	Effective Vol. m^3	Normal Operating Depth (m)
A_1	38.5	704,000	1.8
A_2	38.4	703,000	1.8
B_1	28.7	586,000	2.0
B_2	29.3	598,000	2.0
C	26.1	580,000	2.2
D	15.9	384,000	2.4
E	11.5	297,000	2.6
Total	188.4	852,000	

Meters x 3.281 = feet; Hectares x 2.471 = acres; Meters^3 x 35.31 = feet^3

adjacent to the chlorination facilities. The filtered effluent was stored for several hours until chlorinated. Each storage tank was covered with a lid to restrict sunlight and algae growth.

The chlorination facilities were designed and constructed during the spring and summer of 1975. The facility was designed to provide four separate treatments or four replicate experiments at the same time. Three units were

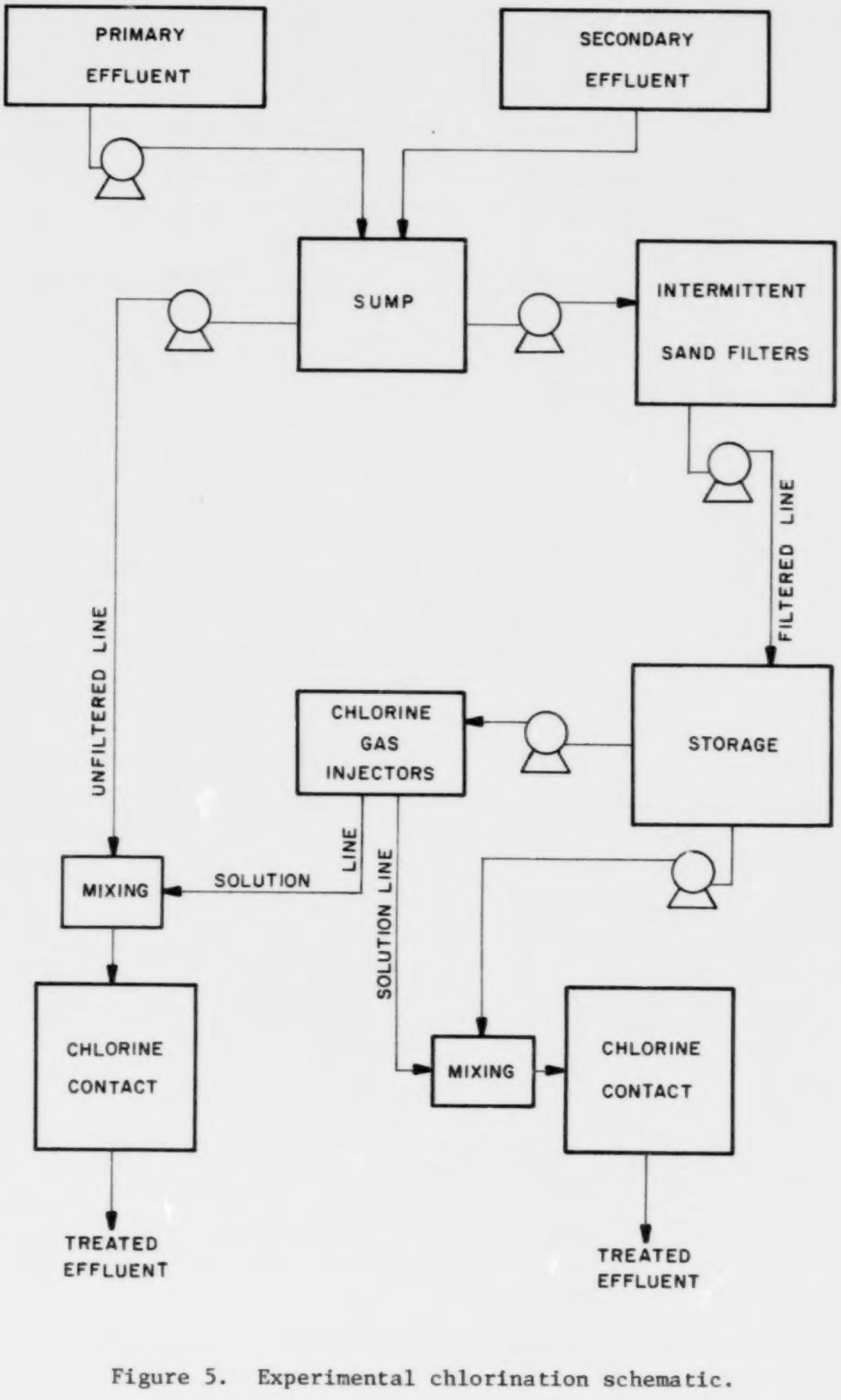

PRIMARY EFFLUENT
SECONDARY EFFLUENT
SUMP
INTERMITTENT SAND FILTERS
FILTERED LINE
UNFILTERED LINE
CHLORINE GAS INJECTORS
STORAGE
SOLUTION LINE
SOLUTION LINE
MIXING
MIXING
CHLORINE CONTACT
CHLORINE CONTACT
TREATED EFFLUENT
TREATED EFFLUENT

Figure 5. Experimental chlorination schematic.

used to chlorinate unfiltered effluent and the fourth was used to chlorinate filtered effluent. General details are shown in Figure 6. The unfiltered effluent was pumped directly from the sump beneath the main pump house to a splitter box, where the wastewater stream was divided into three equal discharges of 190 m^3/day (50,000 gpd) each. The filtered effluent was pumped from the storage tanks to the splitter box where a separate flow of 190 m^3/day (50,000 gpd) was discharged to the fourth unit. Each of the four equal streams of effluent flowed from the splitter box into identically designed mixing chambers and contact tanks.

Each mixing chamber was designed to provide a 30 second detention time. During this short time, the chlorine solution was added to the flow from the splitter box and mixed by use of an underflow baffle with a variable speed mechanical mixer.[1] The chlorinated wastewater then flowed over a rectangular weir into the contact tank.

The water used to prepare the chlorine solution was filtered effluent. The filtered water was pumped from the storage tanks to a chlorination house where it passed through a Y-strainer before being mixed with chlorine gas. The appropriate quantity of chlorine gas and the water were mixed with a vacuum operated diffuser. The flow in each solution line was measured with a rotameter[2] before being introduced into the mixing chamber. The rotameter had a capacity of 27.2 lpm (7.2 gpm) at 100 percent of flow and an accuracy of ± 2 percent. The gas flow to the injectors was also measured with a rotameter attached to the vacuum operated chlorinators[3] used in this study.

The contact tanks were designed according to recommended practices outlined in the literature review section. Attempts were made to produce plug flow conditions. The longitudinal serpentine configuration was adopted as being the most likely practical configuration to produce plug flow. An effective length to width ratio of 25:1 was used. Additional baffles were inserted near the inlet and outlet of each tank to enhance hydraulic characteristics. The baffle near the inlet was an under-flow perforated baffle and was useful in reducing dead spaces. At the outlet, a perforated over-flow baffle was used. This not only evenly distributed the flow across the width and depth of the tank, but also provided a way to remove floatables from the tank. The chlorinated effluent from the contact tanks was discharged into an irrigation ditch nearby. Details of the mixing chamber and contact tank design are shown in Figure 7.

HYDRAULIC PERFORMANCE

The hydraulic performance of each contact tank was determined by conducting dye studies. Rhodamine B was used as the tracer dye. A given concentration of this fluorescent dye was injected into the mixing chamber and a fluorometer was used to monitor the concentration of dye at given points in the tank at

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[1] Lightnin Model 10.

[2] Fischer and Porter No. 10A1027A.

[3] Fischer and Porter Model 70C1710100.

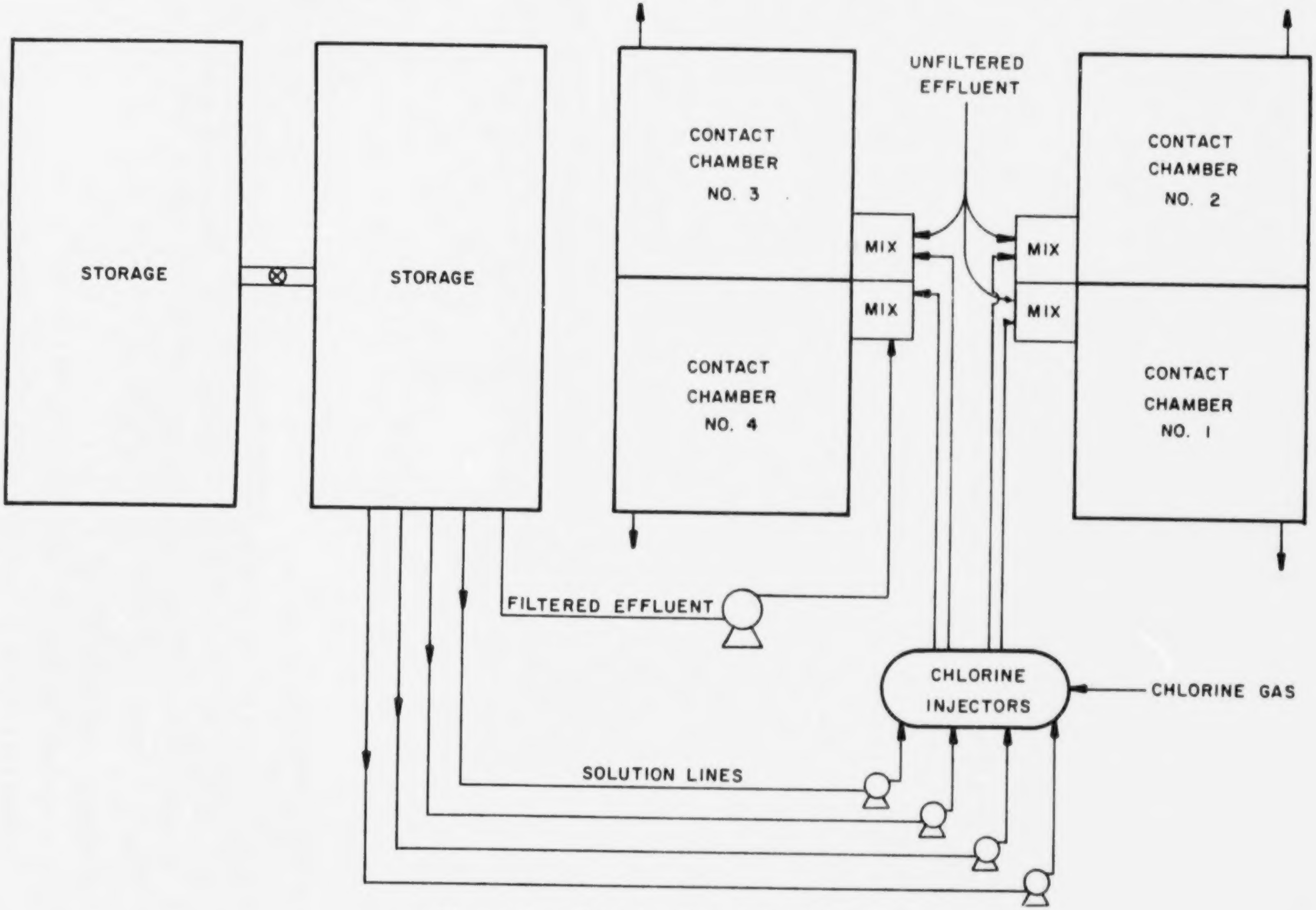

STORAGE
STORAGE
CONTACT CHAMBER NO. 3
CONTACT CHAMBER NO. 4
UNFILTERED EFFLUENT
MIX
MIX
MIX
MIX
CONTACT CHAMBER NO. 2
CONTACT CHAMBER NO. 1
FILTERED EFFLUENT
CHLORINE INJECTORS
CHLORINE GAS
SOLUTION LINES

Figure 6. Chlorination facilities.

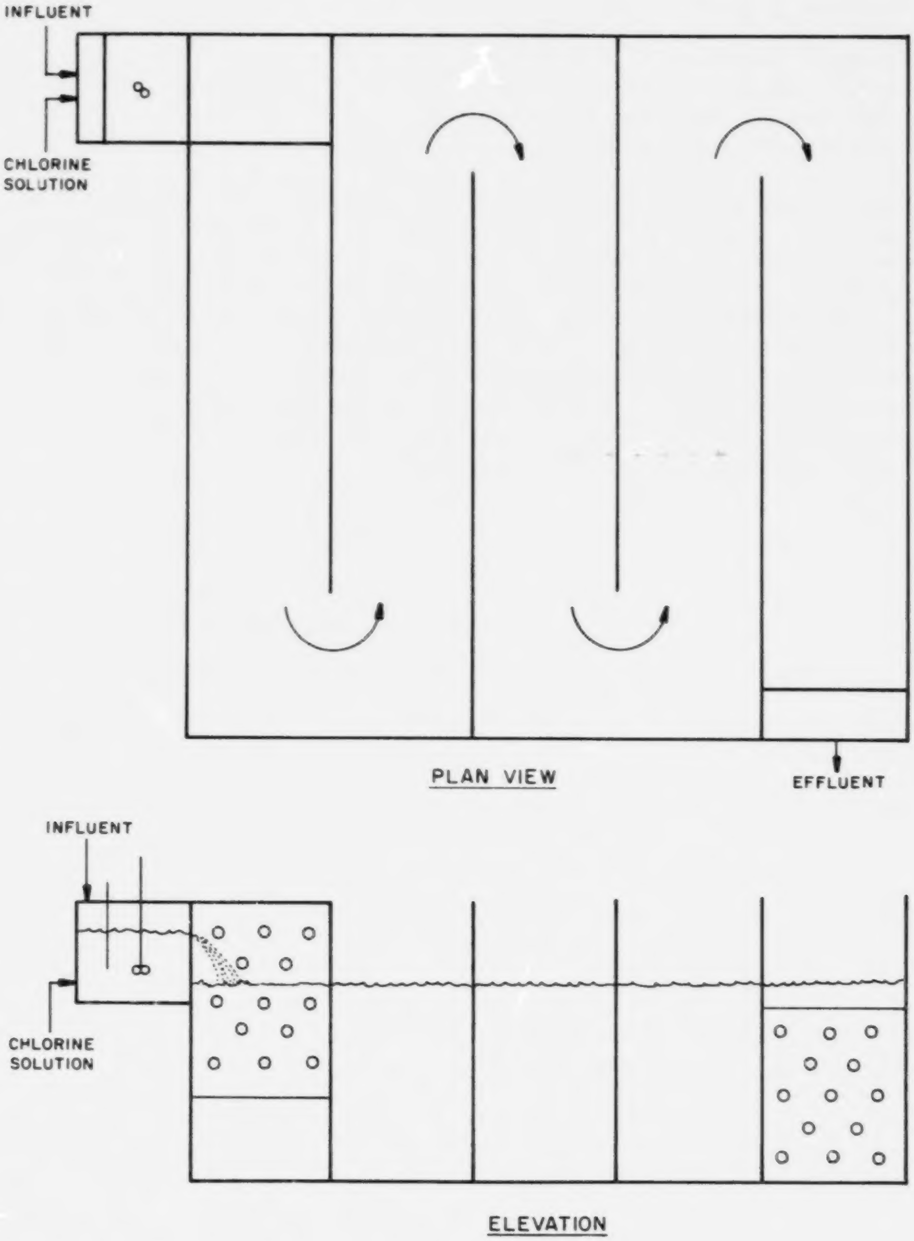

INFLUENT
CHLORINE SOLUTION
PLAN VIEW
EFFLUENT
INFLUENT
CHLORINE SOLUTION
ELEVATION

Figure 7. Chlorine mixing and contact tanks.

specific time intervals. Samples were taken at approximately one-third and two-thirds the distance through the tanks and at the tank outlets. Care was taken in positioning the sample points to avoid the effects of dead spaces and eddy currents. It was found that samples collected at the surface were not representative of the true hydraulic characteristics of the tank. Therefore, a rigid siphoning apparatus was devised to draw samples from the mid-width of the channel and at one-half the water depth. This apparatus was not only useful in collecting representative samples, but it also prevented the disruption of the water surface during sample collection.

Results from the tracer studies were analyzed using conventional methods referred to in the literature review section. Although this is not the most accurate approach to determining hydraulic performance, it is the most commonly used and, consequently, the most useful in comparing data with literature values. Actual detention times were compared with the theoretical detention time of one hour. Results of the tracer studies are shown graphically in Figures 8-11. Characteristic performance indices are summarized in Table 2. Although these indices do not indicate perfect plug flow conditions, they do indicate that the contact tanks approach plug flow more closely than most contact tanks currently used (Deaner, undated).

TABLE 2. SUMMARY OF DYE STUDIES

Contact Tank	Sample Number	Average Time (Min.)				T_m/T	T_h/T	T_a/T	Morrell Index
		T	T_m	T_h	T_a				
#1	12	18.2	9.3	15.3	17.4	0.51	0.84	0.95	3.09
	13	37.7	25.5	30.8	34.9	0.68	0.82	0.93	2.45
	14	54.6	38.3	44.3	47.7	0.70	0.81	0.87	2.17
#2	15	18.2	10.7	15.3	16.8	0.58	0.84	0.92	2.65
	16	37.7	26.0	31.3	32.9	0.69	0.83	0.87	2.32
	17	54.6	35.7	42.2	47.1	0.65	0.77	0.86	2.29
#3	18	18.2	11.0	15.2	17.6	0.60	0.83	0.97	3.35
	19	37.7	28.0	34.0	35.1	0.75	0.91	0.93	2.22
	20	54.6	38.3	46.0	50.3	0.70	0.84	0.92	2.38
#4	21	18.2	11.5	16.3	18.1	0.63	0.90	0.99	3.44
	22	37.7	31.5	34.8	36.9	0.84	0.92	0.98	2.21
	23	54.6	47.5	51.0	53.3	0.86	0.93	0.98	1.85

T_m = modal time (time to reach peak tracer concentration).
T_h = mean time (time for half the tracer to pass the sampling point).
T_a = average time (time at which the centroid of the dispersion curve is located).
Morrell Index = time at which 90 percent of the tracer has passed the sampling point divided by the time at which 10 percent of the tracer passed the same point (T_{90}/T_{10}).
T_m/T = index of modal detention time.
T_h/T = index of mean detention time.
T_a/T = index of average detention time.

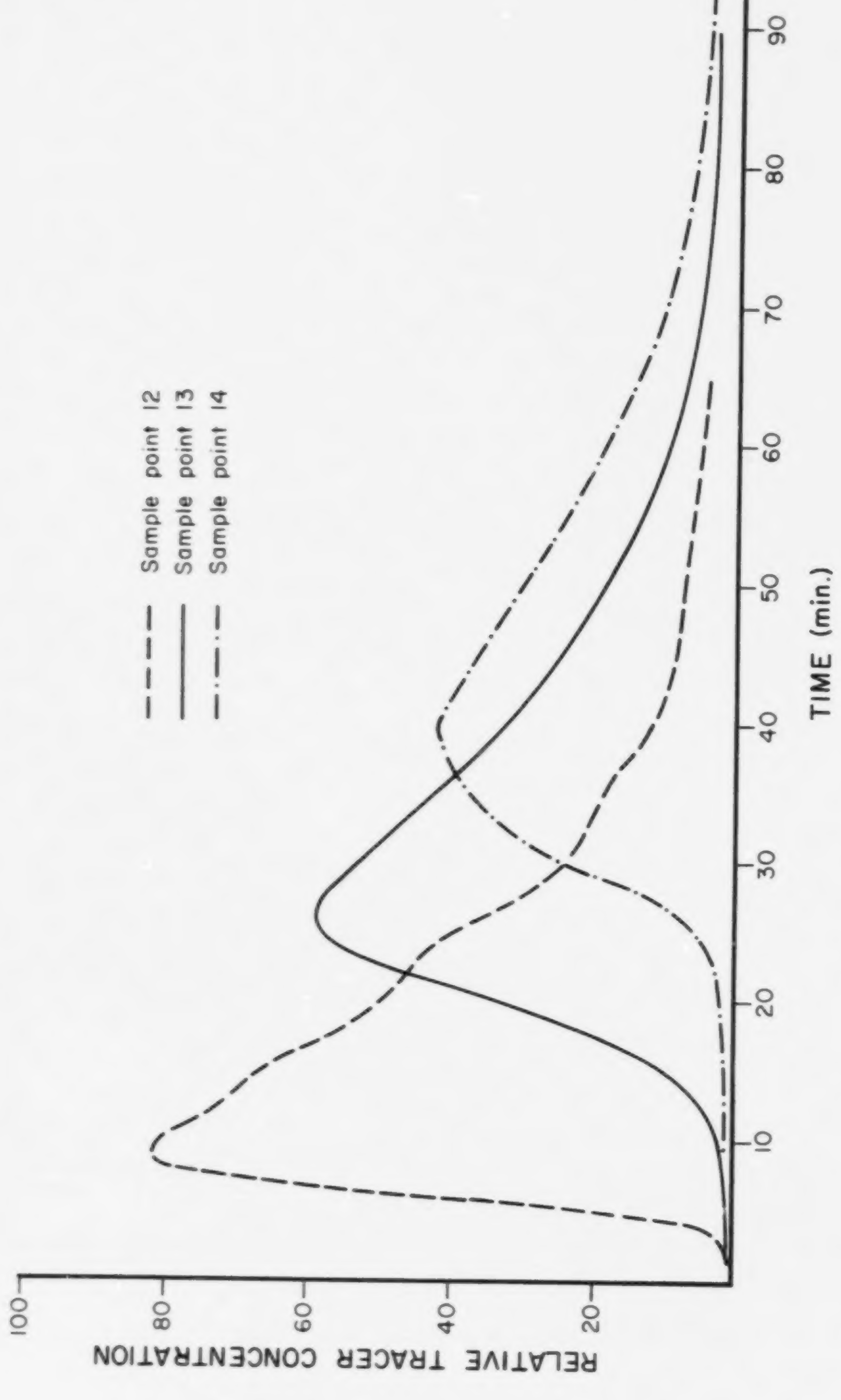


Figure 8. Hydraulic performance--contact tank no. 1.

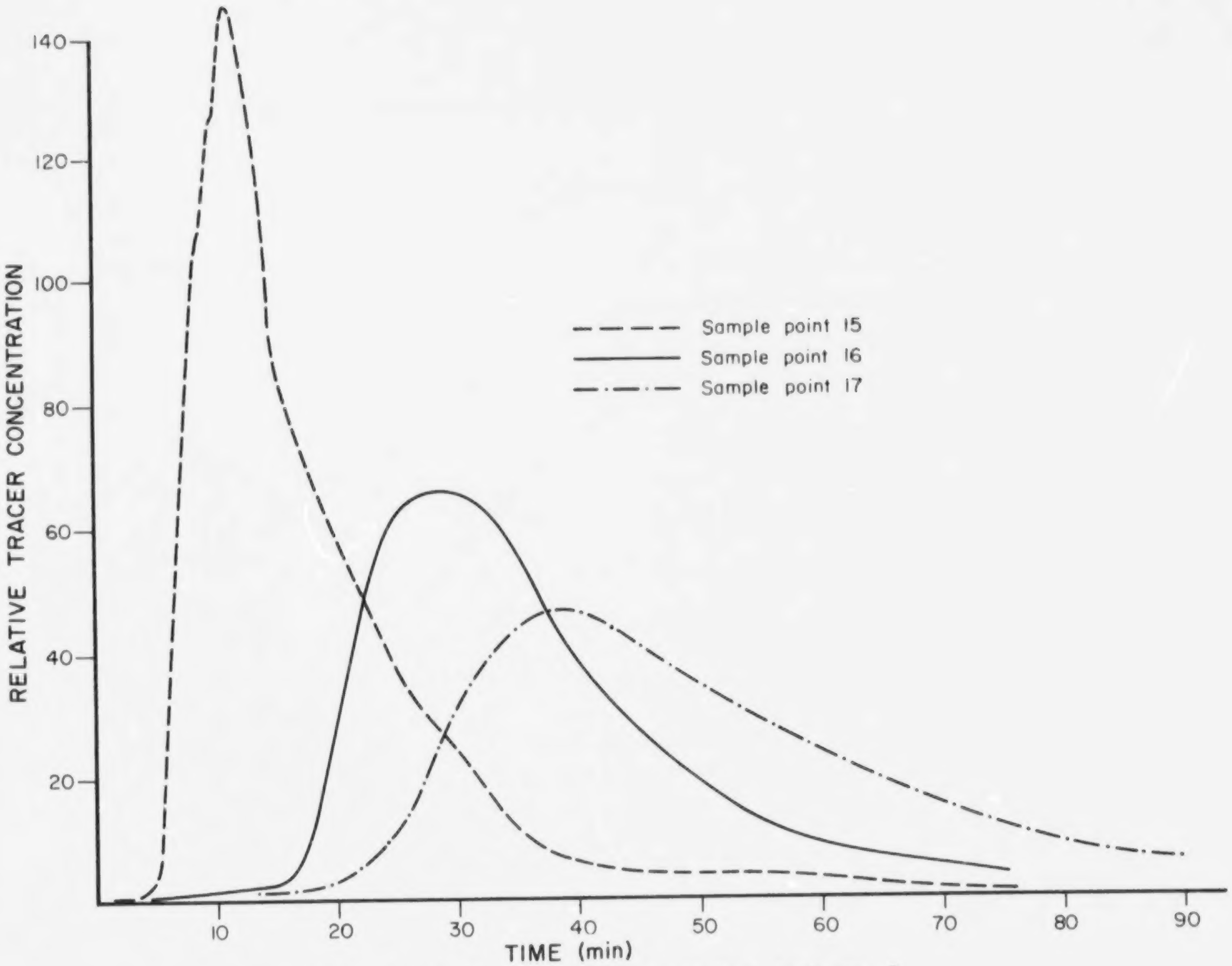


Figure 9. Hydraulic performance--contact tank no. 2.

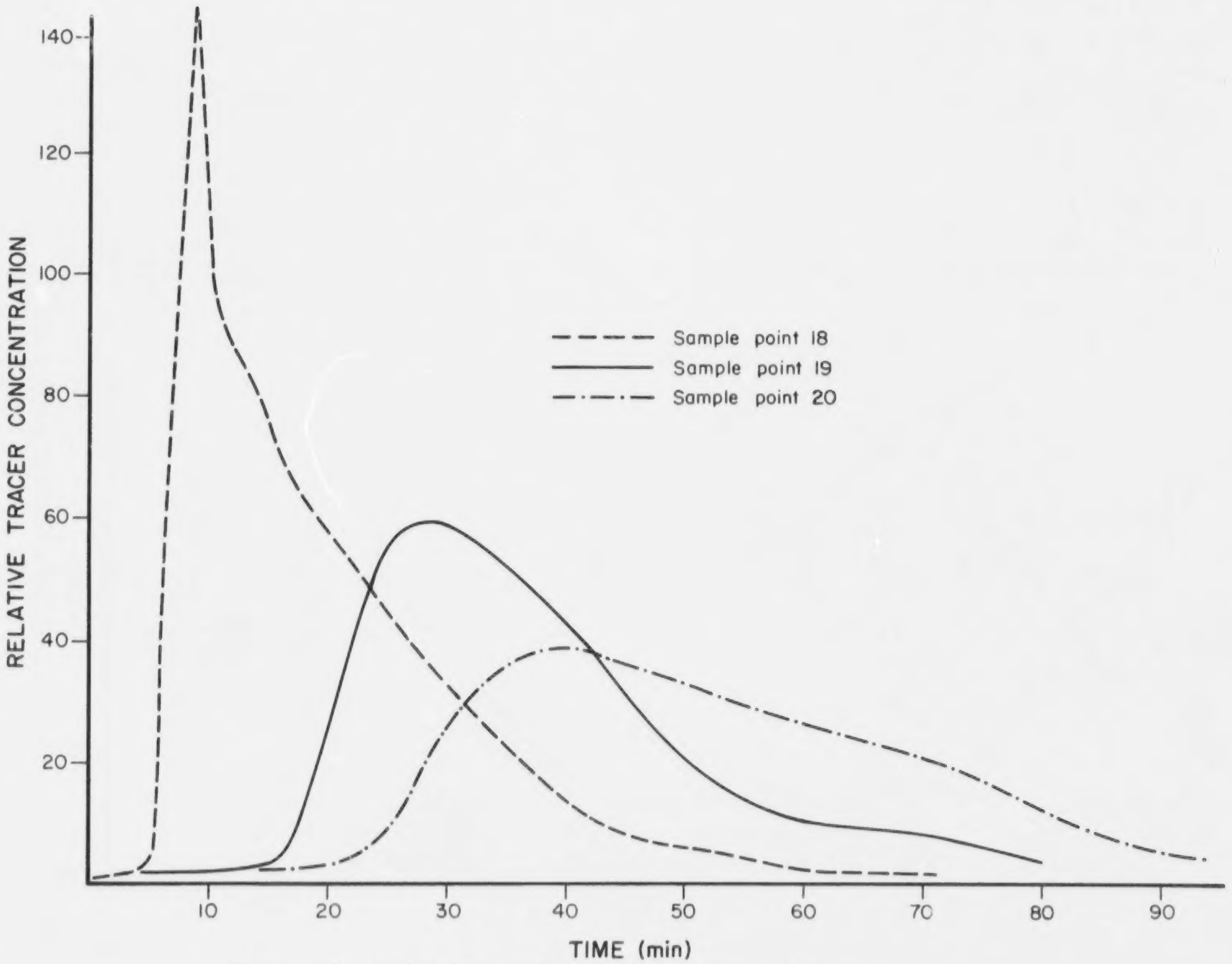


Figure 10. Hydraulic performance--contact tank no. 3.

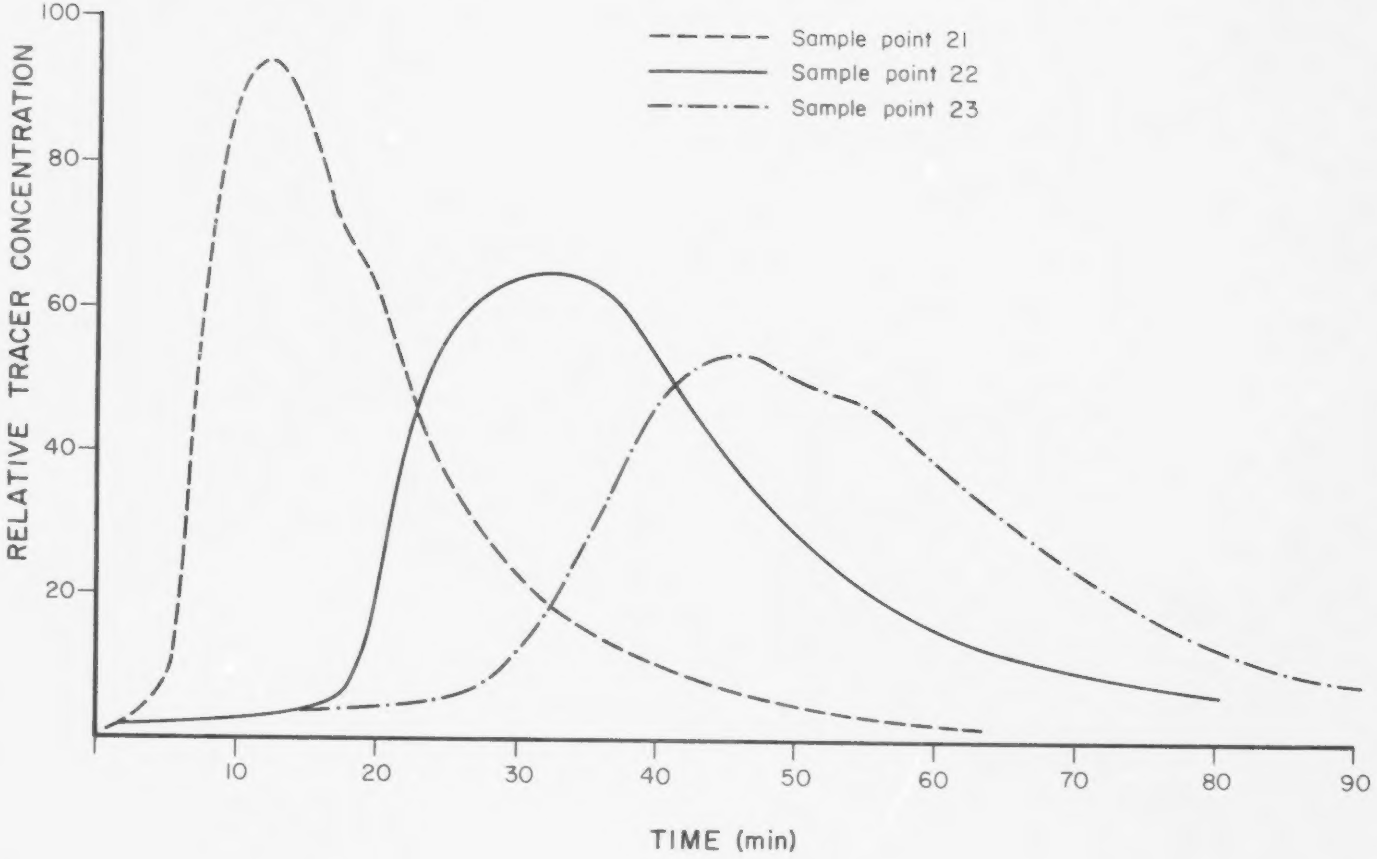


Figure 11. Hydraulic performance--contact tank no. 4.

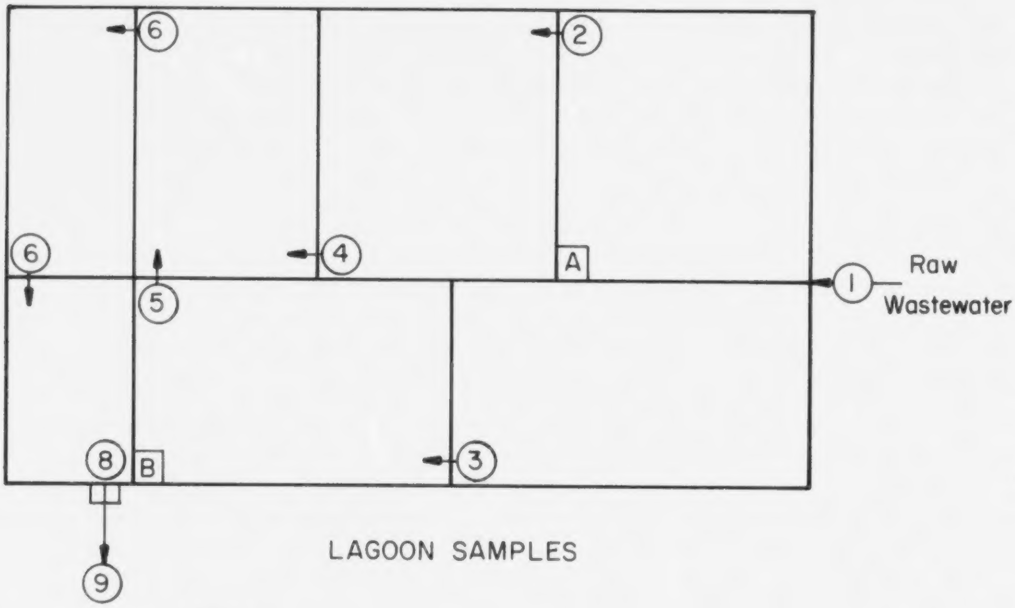
SAMPLING AND ANALYTICAL PROCEDURE

Chlorination of secondary lagoon effluent was started in early August, 1975. Chlorine dosages in the four contact tanks were varied between 0.25 and 30.0 mg/l. Samples of filtered and unfiltered effluent were collected before chlorination and at three different points in each contact tank. The points in the contact tanks were at approximately one-third and two-thirds the hydraulic distance through each tank and at the tank outlets. Samples were collected at the mid-water depth in each tank. Initially, the sampling apparatus was used at all sampling locations except the outlets, where samples were withdrawn from a port located at mid-depth. Later, it was found that the accumulation of solids on the outlet baffle and around the port affected the collection of representative bacteriological samples. Thereafter, a siphoning apparatus was also used to collect samples at the outlets. At the beginning of each experiment, a time span equal to at least two mean residence times was allowed to elapse before samples were collected.

Samples were also collected from the influent and effluent of each cell of the lagoon system. This was done to characterize the performance of the lagoon system and as an aid in determining how to adjust chlorination practices to compensate for seasonal fluctuations in lagoon performance. All samples were collected at least twice per week. From December, 1975, through February, 1976, collection of chlorinated samples was suspended because of low coliform counts in the secondary effluent and because of freezing problems, primarily in the pipeline from the primary cell to the pump house. Collection of lagoon samples was continued on a regular basis during this period. From June through August, 1976, the collection frequency of chlorinated samples was doubled to provide a greater data base from which to develop a mathematical model. Sampling was concluded on August 24, 1976. The locations of all sampling stations are shown in Figure 12 and described in Table 3. Points A and B indicate the locations at which unfiltered lagoon effluents were withdrawn from the lagoon system.

Bacteriological analyses included confirmed MPN total and fecal coliforms at all 23 sampling stations. Five tubes were used for each dilution. Membrane filter total and fecal coliform counts were also determined on all unchlorinated samples. Procedures described in Standard Methods (1971) were followed. Samples were collected in autoclaved bottles. For chlorinated samples, sodium sulfite was contained in each sample bottle to neutralize excess chlorine. The siphoning apparatus was flushed with boiling water before collecting bacteriological samples from the chlorine contact tanks.

Table 4 shows which parameters were analyzed at each sampling site. Besides the bacteriological parameters, samples were analyzed for ammonia nitrogen (NH_3-N), biochemical oxygen demand (BOD_5), dissolved oxygen (DO), total chemical oxygen demand (TCOD), soluble chemical oxygen demand (SCOD), sulfide ($S^=$), suspended solids (SS), volatile suspended solids (VSS), free chlorine residual (FCl), combined chlorine residual (CCl), temperature, pH, and turbidity. For chlorinated samples, sodium sulfite was used to dechlorinate. Temperature, DO (measured with a DO probe), and residual chlorine were determined in the field. The samples were then returned to the Utah Water Research Laboratory to complete the other analyses. Chlorine residual was

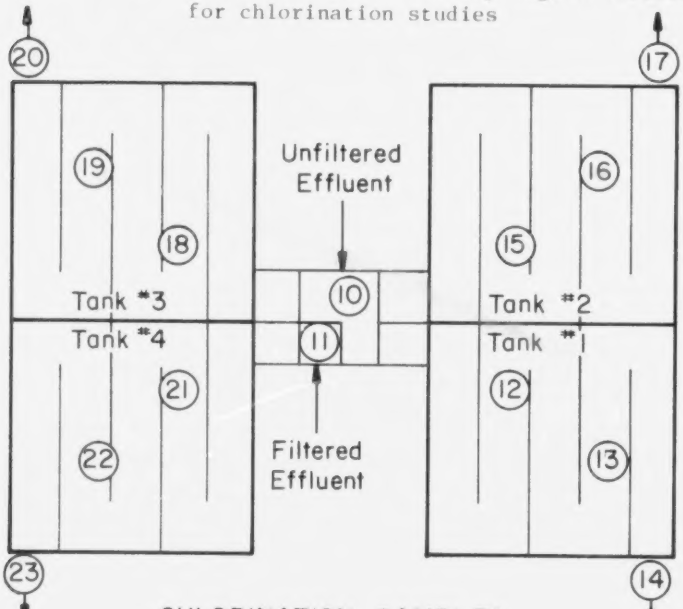

6
2
6
4
A
1
Raw
Wastewater
5
8
B
3
9

LAGOON SAMPLES

Legend

A = point at which primary lagoon effluent was taken for chlorination studies

B = point at which secondary lagoon effluent was taken for chlorination studies


20
17
19
16
Unfiltered
Effluent
18
15
10
Tank #3
Tank #2
Tank #4
Tank #1
11
21
12
22
13
Filtered
Effluent
23
14

CHLORINATION SAMPLES

Figure 12. Location of lagoon and chlorination samples.

TABLE 3. DESCRIPTION OF SAMPLE LOCATIONS SHOWN IN FIGURE 12

Sample No.	Site Description
1	Raw wastewater influent to Logan Lagoon System
2	Effluent from Primary Cell A_2
3	Effluent from Primary Cell A_1
4	Effluent from Secondary Cell B_2
5	Effluent from Secondary Cell B_1
6	Effluent from First Tertiary Cell C
7	Effluent from Second Tertiary Cell D
8	Effluent from Third Tertiary Cell E
9	Final Logan Lagoon System Effluent (effluent from Cell E passes through a small holding cell before discharge from the system)
10	Raw influent to chlorination system
11	Filtered influent to chlorination system
12	Chlorine Contact Chamber No. 1, θ = 18 min.
13	Chlorine Contact Chamber No. 1, θ = 35 min.
14	Chlorine Contact Chamber No. 1, θ = 50 min.
15	Chlorine Contact Chamber No. 2, θ = 18 min.
16	Chlorine Contact Chamber No. 2, θ = 35 min.
17	Chlorine Contact Chamber No. 2, θ = 50 min.
18	Chlorine Contact Chamber No. 3, θ = 18 min.
19	Chlorine Contact Chamber No. 3, θ = 35 min.
20	Chlorine Contact Chamber No. 3, θ = 50 min.
21	Chlorine Contact Chamber, No. 4, (filtered), θ = 18 min.
22	Chlorine Contact Chamber, No. 4, (filtered), θ = 35 min.
23	Chlorine Contact Chamber, No. 4, (filtered), θ = 50 min.

measured with an amperometric titrator.[4] Combined residual was measured using the back titration method for analysis as described in Standard Methods (1971). Free chlorine residual was measured using the forward titration method. All other analyses were performed according to procedures outlined in Standard Methods (1971) with the exception of sulfide ($S^=$). $S^=$ samples were collected in separate sample bottles containing a stabilizing solution suggested by Orion Research Incorporated (undated). The samples were then returned to the laboratory and analyzed using an Orion sulfide ion electrode.[5]

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[4] Manufactured by Wallace-Tiernan.

[5] Manufactured by Orion.

TABLE 4. SAMPLE SITE DESCRIPTION AND ANALYSES TO BE PERFORMED

Sample No.	Description	Analysis to be Performed										
		BOD	Unfilt. COD	Sol. COD	NH_3	$S^=$	Turb.	SS & VSS	pH Temp. DO	Total Coli. (MPN) & (MF)	Fecal Coli. (MPN) & (MF)	Cl_2 Res.
1	Raw Wastewater	X	X	X	X			X	X	XX	XX	
2,3,4,5,6,7,8,9	Lagoon Cell Effluents								X	XX	XX	
10	Raw Primary or Secondary Effluent	X	X	X	X	X	X	X	X	XX	XX	
11	Filtered Primary or Secondary Effluent	X	X	X	X	X	X	X	X	XX	XX	
12,13,14,15,16,17,18,19,20,21,22,23	Chlorinated Effluents		X[b]	X	X	X	X	X	X	X[a]	X[a]	X

[a] MF not performed.

[b] Unfiltered COD performed on Samples 14, 17, 20, and 23 only.

LABORATORY AND FIELD EXPERIMENTATION

In developing a model for optimizing chlorination of algae laden waters, it was necessary to conduct laboratory and field studies in addition to the regular collection of field data. These studies were essential in the identification and quantification of several important relationships.

One of the relationships not clearly defined in the literature deals with the effect of chlorine on measured ammonia. Initially it was not known if ammonia, as determined in the laboratory, represented NH_3-N only or if it also included the amine associated with chloramine. To determine this, samples containing three different known concentrations of ammonia were prepared by adding appropriate quantities of ammonium chloride (NH_4Cl) to deionized distilled water (DDW). Samples representing each of the ammonia concentrations were then dosed with three different concentrations of chlorine. The chlorine dosages were prepared from a standard solution of sodium hypochlorite (NaOCl). The chlorinated samples were mixed using a laboratory stirrer.[6] After five and 15 minutes of contact, the samples were analyzed for ammonia and for total and free chlorine residual using the amperometric titrator.[7]

As the literature indicates, in wastewater chlorination, chlorine not only reacts with NH_3-N, but also with organic nitrogen. This greatly affects the shape of the breakpoint curve, as previously discussed. To get an indication of the ratio of organic nitrogen to NH_3-N present in a waste stabilization lagoon and an idea of how that organic nitrogen affects breakpoint chlorination, field samples were collected on three separate sampling days in August, 1976, and analyzed for total kjeldahl nitrogen (TKN). The samples represented high and low chlorine doses, as well as no chlorine. TKN analysis was performed according to Standard Methods (1971).

Other relationships which have generally been left unquantified include the effects of chlorine on total chemical oxygen demand (TCOD), soluble chemical oxygen demand (SCOD), suspended solids (SS), volatile suspended solids (VSS), and turbidity. In an attempt to more satisfactorily define these relationships, two samples of primary lagoon effluent were collected during different times of the year and returned to the laboratory for experimentation. The first sample was collected in April, 1976, during the peak of an algae bloom. TCOD, SCOD, and SS concentrations were relatively high. Half of the samples were spiked with potassium acid phthalate to create another sample with even higher TCOD and SCOD concentrations.

The second sample was collected in August, 1976, during a period when algae, TCOD, SCOD, and SS concentrations were relatively low. Upon returning to the laboratory, the lagoon samples were each dosed with several different concentrations of a chlorine solution prepared from sodium hypochlorite and standardized with the amperometric titrator. The samples were then mixed with a laboratory stirrer. Each sample was mixed rapidly at maximum stirring speed for the first 60 seconds of contact time and then at 60 rpm for the remainder of the test. After contact periods of 15, 60, and 120 minutes, aliquots were taken and analyzed for TCOD, SCOD, SS, VSS, turbidity, free chlorine, and combined chlorine.

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[6] Manufactured by Phipps and Bird (Model 5P36DA1A, series 3325).

[7] Manufactured by Wallace and Tiernan.

Since the laboratory tests were conducted using completely mixed reactors, it was assumed that any changes occurring in SS and VSS concentrations were attributable to the oxidizing action of chlorine on the suspended solids, and not to settling. However, in the field, the settling of SS was observed in the chlorine contact tanks. To determine changes in SS due to settling and changes due to the breakdown of SS by chlorine, a field study was conducted during August, 1976. In each of three chlorine contact tanks, one-gallon containers were placed after the inlet baffle, in the middle of the tank, and just before the outlet baffle. Secondary lagoon effluent was then allowed to flow through each tank and chlorine dosages of 0, 4, and 20 mg/l were applied. This chlorination practice was allowed to continue, undisturbed, for one week. SS concentrations were measured at the beginning and at the end of the study period. The containers in the contact tanks were returned to the laboratory at the end of the study period, where they were dried and weighed to determine relative amounts of settling at different positions in the tanks.

DATA ANALYSIS

Each data set was given an index number and placed on file with the Burroughs 6700 computer at Utah State University. Data having similar ranges of values were averaged and used as data points for model calibration. When linear regression analyses were performed, a statistical package (STATPAC) prepared by Hurst (undated) was used to perform the regression and to calculate correlation coefficients. Use of correlation coefficients in determining significant levels was made as described by Mendenhall (1971) and Middlebrooks (1976). All correlation coefficients, R and R^2, are significant to the 95 percent confidence level unless otherwise indicated.

Those figures which have more than one regression line shown were tested to determine if, in fact, the slopes of the lines were different. This was accomplished by using statistical formulas which employ sum of squares, sum of products, degrees of freedom, and sample regression coefficients (Steel and Torrie, 1960).

All field and laboratory results for the entire study period are listed in the Appendix. All these results were obtained using methods, procedures, and calculations described earlier with the exception of total and fecal coliform concentrations. Coliform counts that are reported as zero are results obtained from the MPN determinations that interpret the number of bacteria to be less than 2. Therefore, in order to work with these data the number zero was substituted. Data which indicated these MPN numbers of less than 2 were not used in performing the statistical work concerned with coliform bacteria. This was done because there was no way of knowing how much less than 2 the number really was.

SECTION 6

RESULTS AND DISCUSSION OF CHLORINATION STUDY

GENERAL

A complete listing of all field data collected for the chlorination phase of this study between August 1, 1975, and August 24, 1976, is contained in Appendix A. From the graphs, it is observed that for some data points, the membrane filter fecal coliform counts were higher than those for total coliform. These data points must be considered in error.

LABORATORY EXPERIMENTS

Measured Ammonia

Laboratory experiments to determine the effects of chlorine on measured ammonia were performed as previously described. The results show that for all cases, except those for which the initial Cl_2:NH_3-N molar ratio exceeded 1:1, the ammonia-nitrogen measurements remained essentially unchanged with chlorination. For Cl_2:NH_3-N molar ratios exceeding 1:1, ammonia concentrations were reduced as predicted by breakpoint reactions. A complete summary of these experimental results is contained in Table 5.

TABLE 5. EFFECTS OF CHLORINE ON MEASURED AMMONIA

Initial NH_3-N Concentration (mg/l)	Initial Chlorine Dose (mg/l)	Contact Period					
		5 min.			15 min.		
		NH_3-N	Free Chlorine	Total Chlorine	NH_3-N	Free Chlorine	Total Chlorine
9.47	21.0	9.87	0.10	19.60	9.70	0.10	20.1
	10.5	9.11	0.60	9.80	9.50	0.50	9.8
	5.25	9.32	0.40	4.90	9.79	0.10	5.05
4.61	21.0	4.77	0.10	19.70	4.84	0.10	19.1
	10.5	4.80	0.30	9.40	4.61	0.10	9.4
	5.25	4.61	0.20	5.20	4.45	0.10	5.05
1.00	10.5	0.51	1.30	3.80	0.14	1.0	3.0
	5.25	0.88	0.20	2.70	1.49	0.10	2.7
	1.0	1.28	0.10	1.00	1.00	0.05	1.00

Although NH_3-N is being converted to chloramines with the addition of chlorine, the results show that no change in measured ammonia occurs until after the point of maximum chloramine formation. This indicates that ammonia as measured by the laboratory technique (Phenate Method, Standard Methods, 1971) is not really a measure of NH_3-N alone, but is also a measure of the chloramines resulting from the reaction between NH_3-N and chlorine. Therefore, any mathematical model using data from analyses of chlorinated samples and accounting for ammonia must be designed to show no change in ammonia concentrations until after the Cl_2:NH_3-N mole ratio has exceeded 1:1, even though an actual decrease of NH_3-N occurs prior to this point.

Organic Nitrogen

An indication of the amount of organic nitrogen in addition to ammonia contained in waste stabilization lagoon effluent (cell A_2) was obtained by measuring the total kjeldahl nitrogen on three consecutive field sample days. The results are shown in Figures 13-15. For the three days, the TKN prior to chlorination varied between 5.6 and 6.8 mg/l, while NH_3-N varied between 2.4 and 4.4 mg/l for the same samples. The fraction of total nitrogen composed of NH_3-N varied between 0.35 and 0.83. These data should not be construed as being typical over the entire study period, but they do reflect the variability in organic nitrogen composition of lagoon effluent and indicate how quickly the nitrogen composition can change.

Upon examination of data obtained on each of the three sample dates, it was observed that on August 17, 1976 (Figure 13), the TKN appeared to be reduced more with a chlorine dose of 10 mg/l than with a dose of 1 mg/l. At the same time, the NH_3-N concentration was relatively unaffected for both chlorine doses. This indicates that chlorine either oxidizes some of the organic nitrogen or it improves the settling of nitrogenous suspended solids. A combination of both probably exists. When 30 mg/l of chlorine was applied, there was reduction in the NH_3-N concentrations. Since the Cl_2:NH_3-N molar ratio exceeded 1:1 (1.66:1), this reduction was expected. There would also be expected a sharp reduction in combined chlorine at this high ratio. However, after 15 minutes, the combined chlorine residual was 17.6 mg/l. (This compares with a combined chlorine residual of 2.1 mg/l and a free chlorine residual of 0.5 mg/l on August 10, 1976 (see Appendix A), when 30 mg/l chlorine was applied to wastewater containing nearly the same NH_3-N concentration.) Although TKN data at 30 mg/l chlorine on August 17 were unavailable, the data suggest that organic nitrogen plays an important role in influencing the shape of the breakpoint curve. It is noted that the Cl_2:TKN ratio was below 1:1 for the sample receiving a dose of 30 mg/l. If chlorine reacts with all forms of total nitrogen, it can be estimated that the Cl_2:TKN molar ratio must exceed 1:1 for the oxidation of organic and inorganic chloramines to take place.

On August 19, 1976 (Figure 14), there was little change in TKN or NH_3-N which could be attributed to changes in chlorine dose, except in the case of the 20 mg/l dose. For this dose, NH_3-N was reduced by 0.8 mg/l. The Cl_2:NH_3-N molar ratio was also slightly above 1:1 for this dose.

On August 24, 1976 (Figure 15), there was little change in the NH_3-N concentration at one and five mg/l chlorine dose. TKN decreased slightly at both

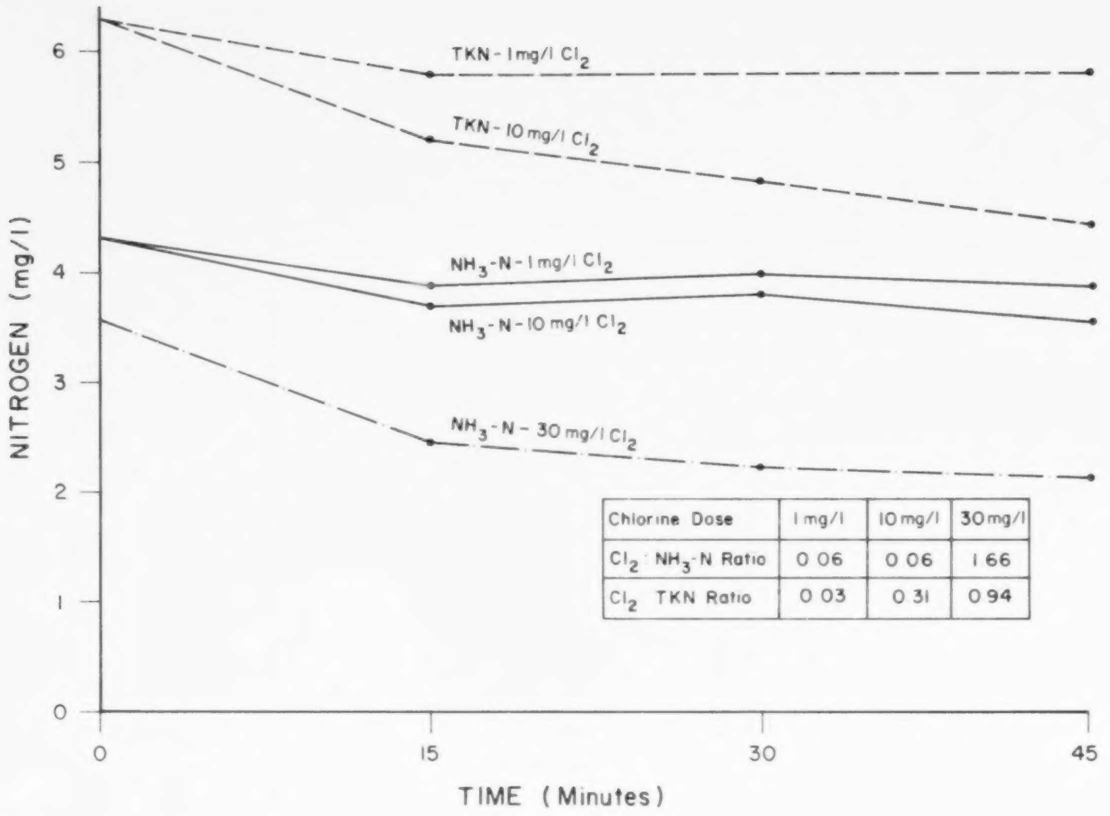
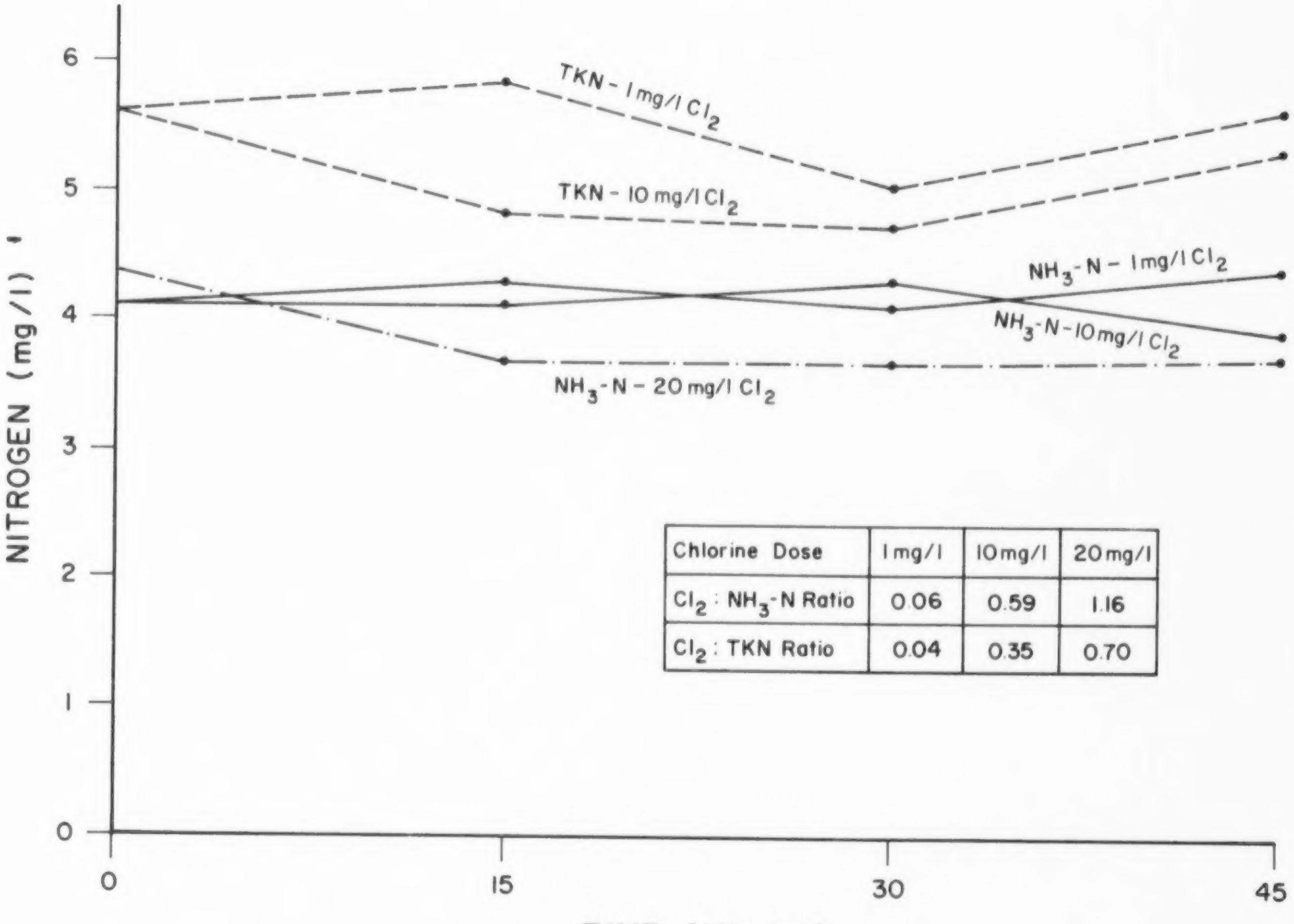


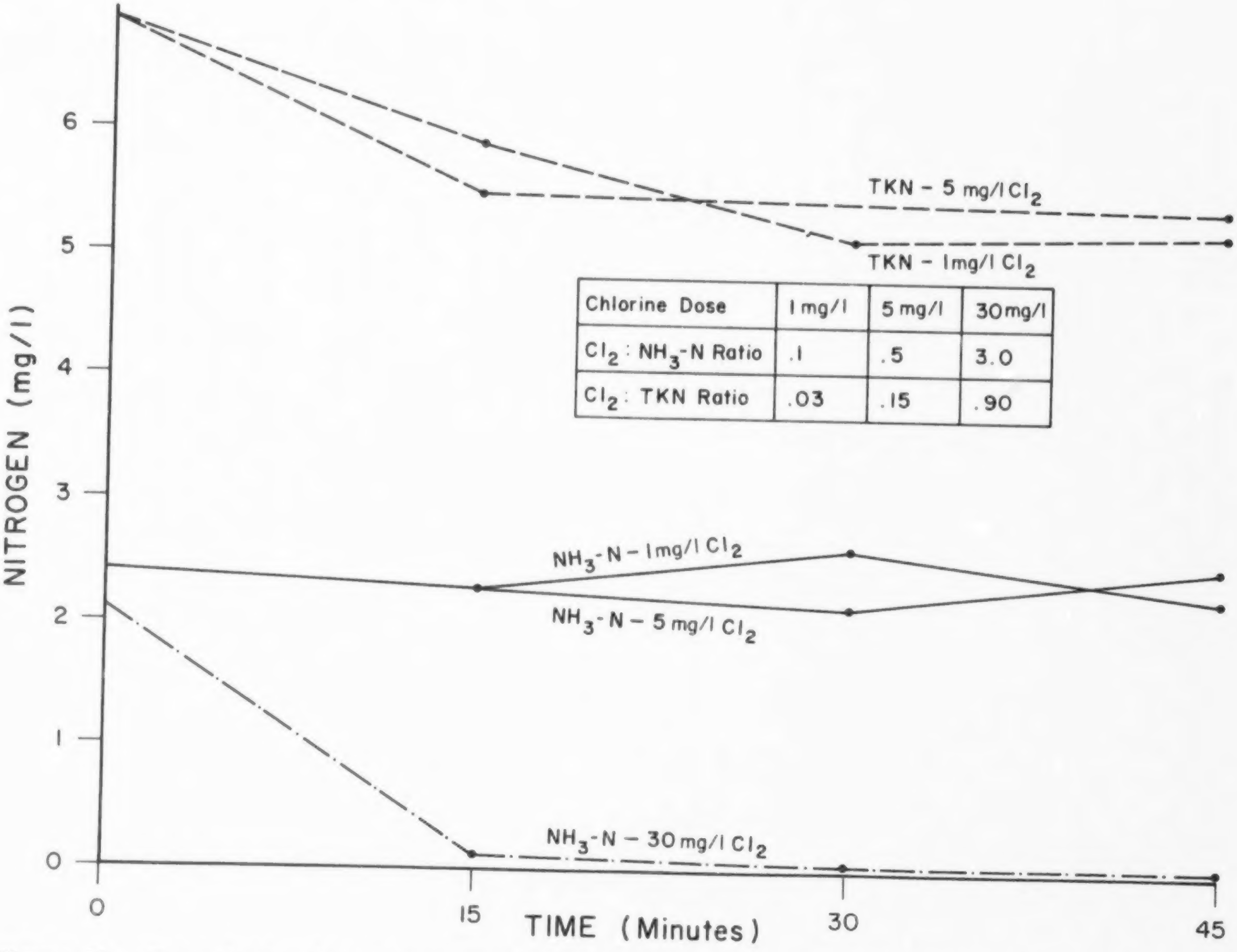
Figure 13. The relationship between Total Kjeldahl Nitrogen (TKN) and ammonia-nitrogen (NH_3-N) in primary lagoon effluent receiving various chlorine dosages and after various chlorine contact periods on August 17, 1976.

doses, probably due to the settling of nitrogenous suspended solids. However, because the NH_3-N concentration in this particular sample was lower than the previous samples, addition of 30 mg/l chlorine removed virtually all the NH_3-N present. This was expected since the molar Cl_2:NH_3-N ratio was 3.0 at this dose. Unfortunately, the TKN data were not available for the 30 mg/l chlorine. The combined chlorine residual of 3.2 mg/l and free chlorine residual of 0.6 mg/l after 15 minutes, however, indicate



Chlorine Dose	1 mg/l	10 mg/l	20 mg/l
Cl_2 : NH_3-N Ratio	0.06	0.59	1.16
Cl_2 : TKN Ratio	0.04	0.35	0.70

Figure 14. The relationship between Total Kjeldahl Nitrogen (TKN) and ammonia-nitrogen (NH_3-N) in primary lagoon effluent receiving various chlorine dosages and after various chlorine contact periods on August 19, 1976.



Chlorine Dose	1 mg/l	5 mg/l	30mg/l
Cl_2 : NH_3-N Ratio	.1	.5	3.0
Cl_2 : TKN Ratio	.03	.15	.90

Figure 15. The relationship between Total Kjeldahl Nitrogen (TKN) and ammonia-nitrogen (NH_3-N) in primary lagoon effluent receiving various chlorine dosages and after various chlorine contact periods on August 24, 1976.

that not all of the compounds formed in the reaction between chlorine and nitrogen were oxidized. One possible explanation of this might be that some compounds formed reactions of chlorine with organic nitrogen could be less susceptible to oxidation than the inorganic chloramines.

From this limited amount of data, it is impossible to make any generalized conclusions concerning the effects of organic nitrogen on wastewater chlorination other than to observe that waste stabilization lagoon effluents may contain two or more times as much total nitrogen as ammonia-nitrogen and that organic nitrogen appears to interfere with theoretical breakpoint reactions. It was also observed that changes in the TKN concentration of lagoon effluent do not necessarily correspond to changes in NH_3-N concentration within the same effluent.

TCOD and SCOD

The effects of chlorine on TCOD and SCOD were evaluated by treating primary lagoon samples, containing three different concentrations of TCOD and SCOD, with a range of chlorine doses varying between 0 and 50.8 mg/l. Details of the experiment have been discussed in Section 5: Method of Procedure. A complete summary of the experimental results is presented in Table 6. It is evident that, for all three concentrations, TCOD remained unchanged throughout the experiment for all chlorine doses.

The SCOD increased with increasing chlorine dose and contact time in the two samples containing large concentrations of algae (i.e., high SS). These data are presented graphically in Figure 16. The same trends, however, were not observed in the sample collected at a later date, when algae concentrations were low. Figure 17 shows very little change in SCOD with increasing time and chlorine dose for this sample. Apparently, increases in SCOD are related to the concentration of algae, as well as to the concentration and form of chlorine residual. Concentrations of COD resulting from suspended matter were not only 60 to 75 mg/l greater for levels I and II than for level III, but the composition was also much different (Figure 16 and Table 6). It appears that the difference between TCOD and SCOD for level III consisted of suspended solids which were resistant to oxidation by chlorine, whereas the increase in SCOD observed in Table 6 and Figure 16 for the level I and level II samples is largely attributable to the release of oxygen demanding materials from lysed algae cells caused by reaction with chlorine. Although increases in SCOD occurred with both combined and free chlorine residuals, changes were most apparent in the presence of free chlorine.

For the two samples showing increases in SCOD, regression analyses were performed. The results are presented in Figure 18. This also shows the relationship between SCOD and increases in chlorine dose and contact time. A linear regression between chlorine dose and changes in SCOD is shown in Figure 19. These results compare favorably with increases in SCOD with algae concentration as presented by Echelberger et al. (1971).

SS, VSS, and Turbidity

The effects of chlorine on SS, VSS, and turbidity were examined using data from Table 6. Since SS concentrations were found to consist almost entirely

TABLE 6. THE EFFECTS OF CHLORINE DOSE ON TOTAL CHEMICAL OXYGEN DEMAND (TCOD), SOLUBLE CHEMICAL OXYGEN DEMAND (SCOD), SUSPENDED SOLIDS (SS), VOLATILE SUSPENDED SOLIDS (VSS), AND TURBIDITY OF PRIMARY LAGOON EFFLUENT SAMPLES COLLECTED ON APRIL 9 AND 10, 1976, AND AUGUST 26, 1976

Date	Cl Dose (mg/l)	Contact Time (min.)	Total COD (mg/l)	Soluble COD (mg/l)	SS (mg/l)	VSS (mg/l)	Turbidity (JTU)	Free Residual (mg/l)	Combined Residual (mg/l)
4/9/76 (Level II)	4.2	0	105.5	24.3	62.1	58.5	12.0	-	-
	-	15	-	19.9	44.9	42.3	12.5	0	4.3
	-	60	-	39.9	42.9	40.4	12.0	0	4.1
	-	120	104.2	27.7	37.8	32.9	12.0	0	3.7
	16.9	0	105.5	24.3	62.1	58.5	12.0	-	-
	-	15	-	23.9	38.3	36.5	13.0	0.30	7.0
	-	60	-	28.4	41.5	39.4	12.5	0.15	5.6
	-	120	100.1	30.7	71.4	49.8	12.5	0.10	4.4
	50.8	0	105.5	24.3	62.1	58.5	12.0	-	-
	-	15	-	34.8	29.7	27.4	16.0	8.5	30.8
	-	60	-	35.8	-	37.0	16.0	5.9	27.6
	-	120	102.0	38.7	40.1	35.3	15.0	4.0	22.0
4/10/76 (Level I)	4.2	0	123.0	52.7	67.2	47.4	13.0	-	-
		15	-	56.2	39.3	42.2	14.0	0	4.0
		60	-	57.1	55.9	44.7	13.0	0	3.6
		120	124.5	59.2	41.1	44.9	13.0	0	3.4
	16.9	0	123.0	52.7	67.2	47.4	13.0	-	-
		15	-	57.9	21.4	43.0	14.0	0.10	7.4
		60	-	57.4	45.1	43.6	14.0	0.10	6.6
		120	124.6	61.2	44.3	43.7	14.0	0.10	5.6
	50.8	0	123.0	52.7	67.2	47.4	13.0	-	-
		15	-	61.2	40.6	44.4	17.5	-	33.6
		60	-	66.0	40.1	39.4	18.0	5.6	27.6
		120	123.7	70.4	40.9	38.2	18.0	3.7	21.6
8/26/76 (Level III)	BLK	0	45.5	26.4	19.0	18.0	8.7	-	-
	-	15	-	27.8	18.4	17.72	8.5	0	0
	-	60	-	23.8	20.2	20.2	9.0	0	0
	-	120	39.1	26.9	17.4	17.4	9.2	0	0
	1.5	0	43.2	28.2	18.2	17.2	11.0	-	-
	-	15	-	25.8	16.7	16.7	10.0	0	1.23
	-	60	-	29.1	17.8	17.8	10.0	0	1.14
	-	120	47.9	28.6	20.0	19.4	8.6	0	1.00
	3.6	0	43.2	28.2	18.2	17.2	11.0	-	-
	-	15	-	28.8	18.0	18.0	10.0	0	3.64
	-	60	-	29.0	18.0	18.0	10.0	0	3.54
	-	120	41.2	24.7	17.8	17.8	8.5	0	3.32
	7.3	0	43.2	28.2	18.2	17.2	11.0	-	-
	-	15	-	28.4	17.9	17.9	10.0	0	7.27
	-	60	-	27.6	17.5	17.3	8.9	0	7.09
	-	120	42.6	27.9	18.2	18.2	8.5	0	6.64
	14.6	0	45.5	26.4	19.0	18.0	8.7	-	-
	-	15	-	27.9	17.4	17.4	9.2	1.00	5.27
	-	60	-	30.3	17.0	17.0	9.0	0.20	2.91
	-	120	42.1	25.9	20.1	19.9	8.6	0.10	1.95
	29.1	0	45.5	26.4	19.0	18.0	8.7	-	-
	-	15	-	28.4	17.6	17.6	9.8	4.40	14.00
	-	60	-	17.1	16.6	16.1	9.3	3.80	12.36
	-	120	-	29.5	16.6	14.8	8.8	2.90	9.27

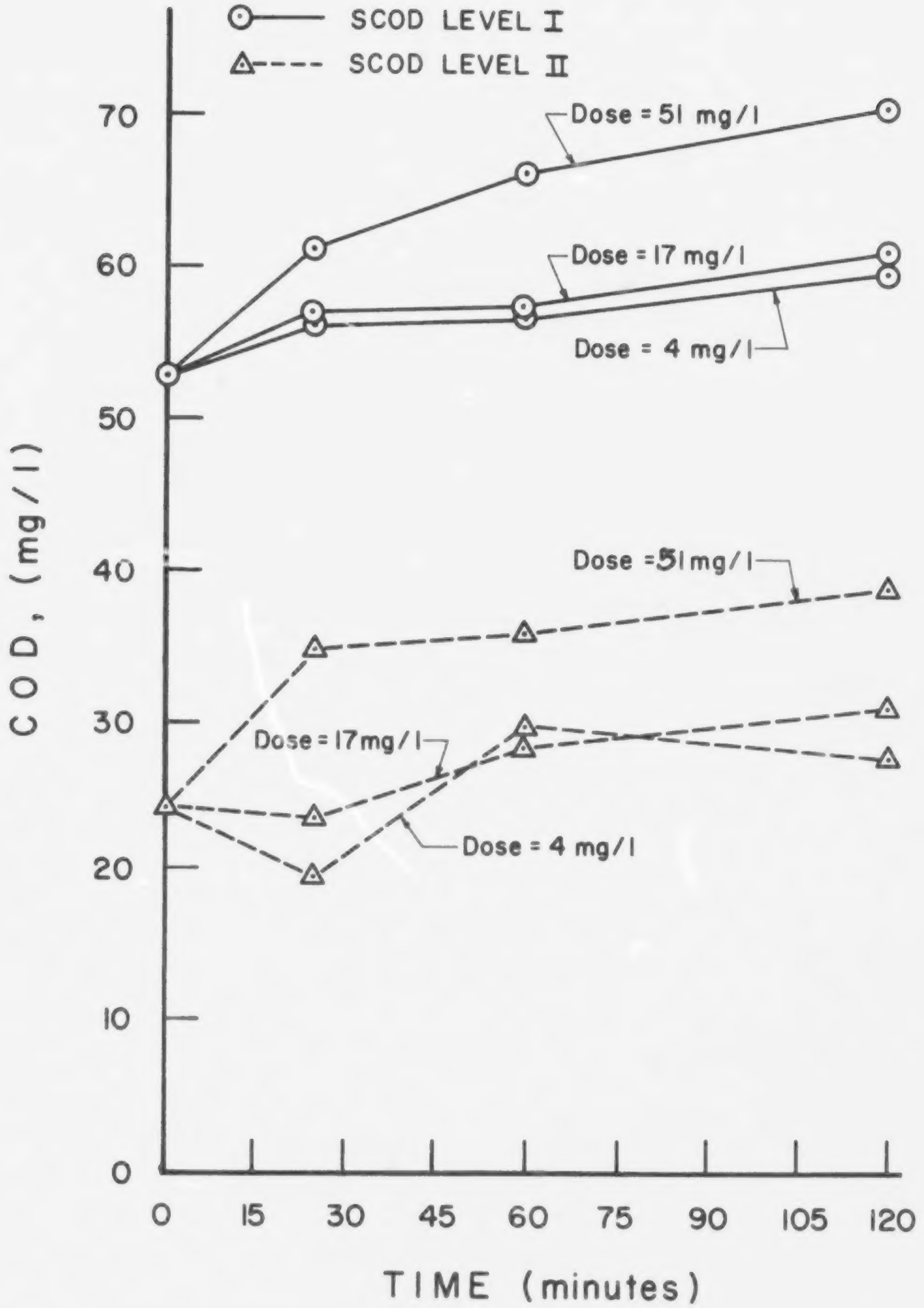


Figure 16. The effect of various chlorine dosages and contact time on various soluble chemical oxygen demand (SCOD) concentrations in primary lagoon samples collected on April 9 and 10, 1976.

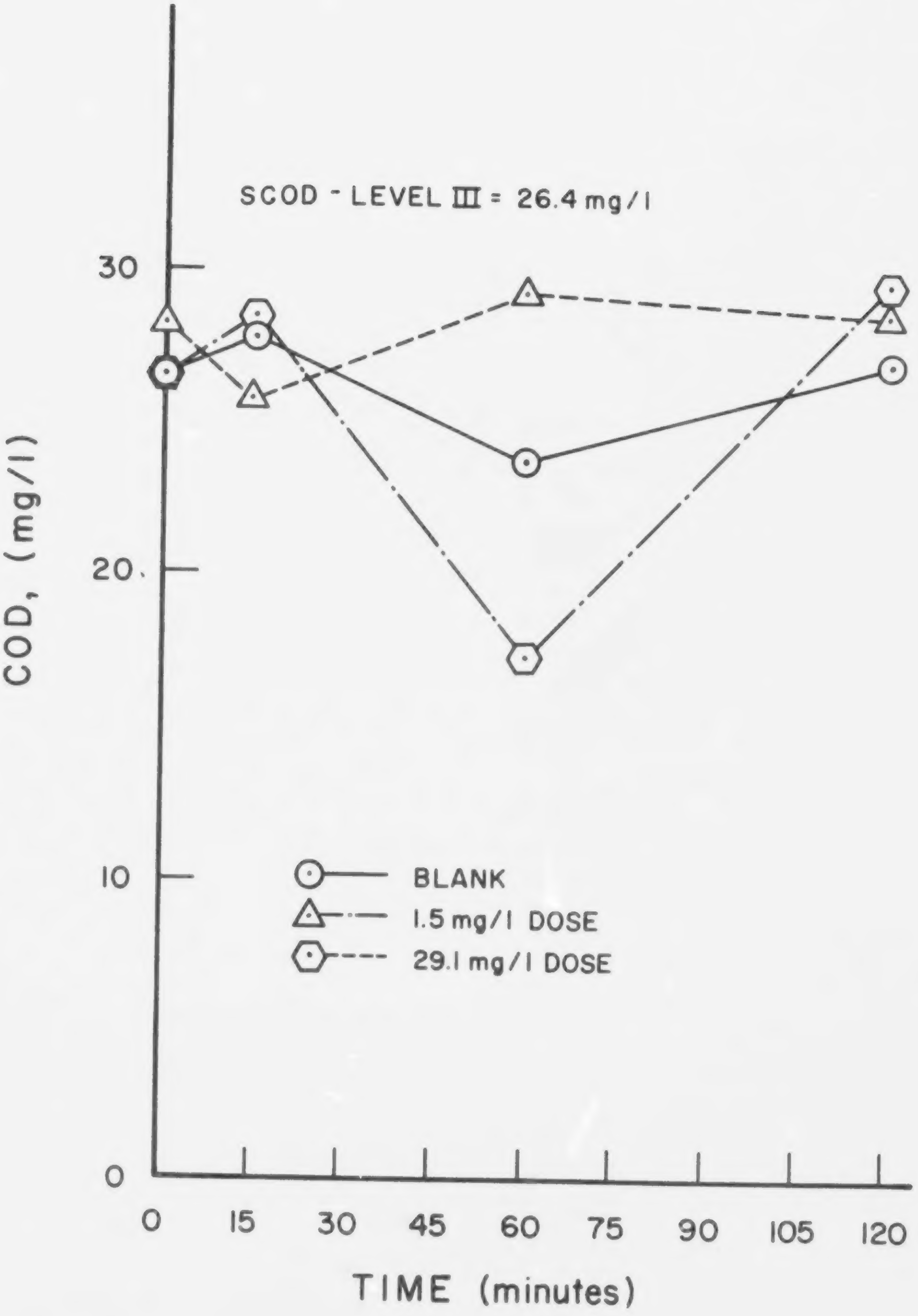


Figure 17. The effect of various chlorine dosages and contact time on various soluble chemical oxygen demand (SCOD) concentrations in primary lagoon samples collected on August 26, 1976.

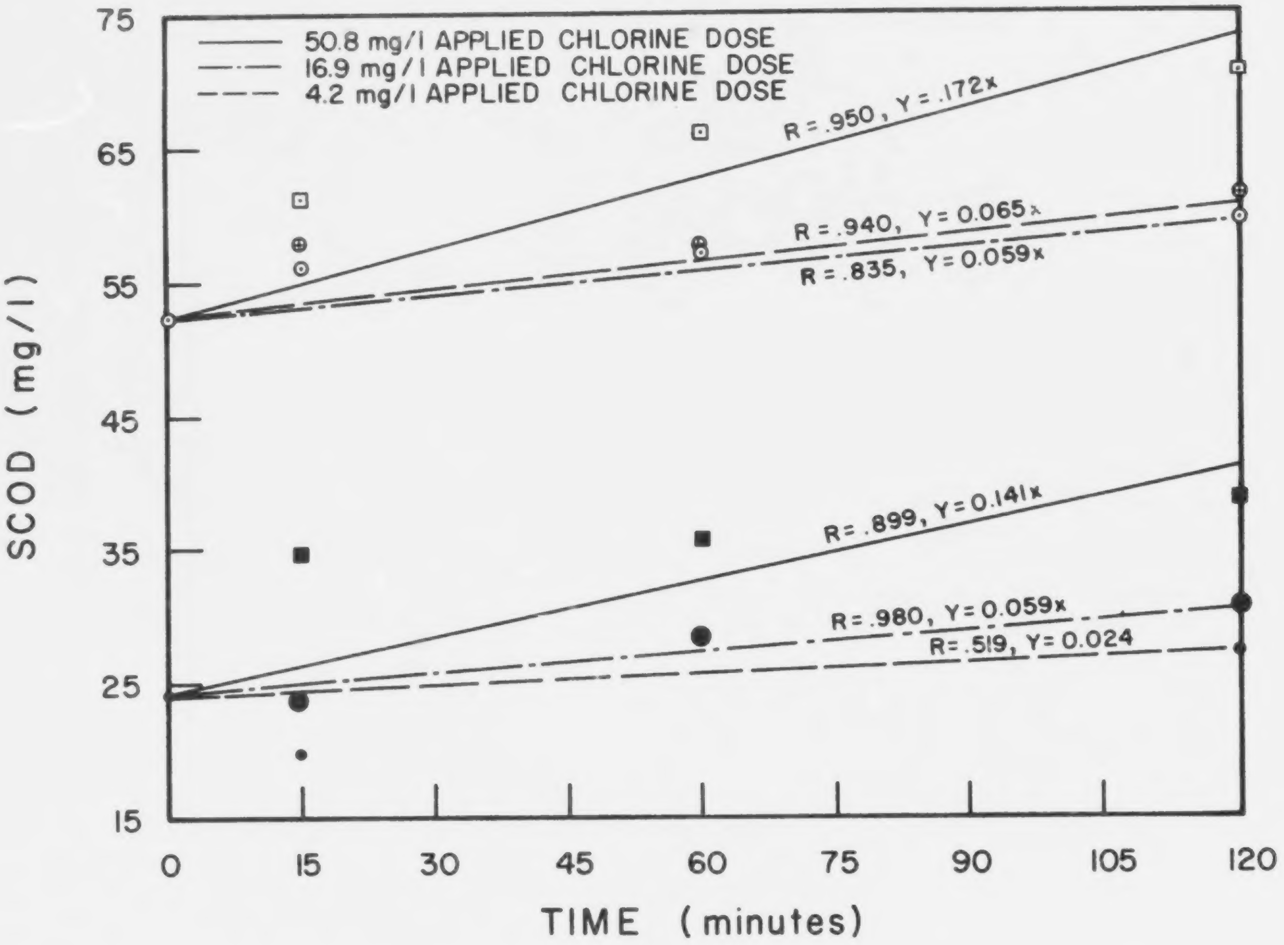


Figure 18. Soluble COD versus chlorine contact time with different chlorine dosages for primary lagoon samples collected on April 9 and 10, 1976.

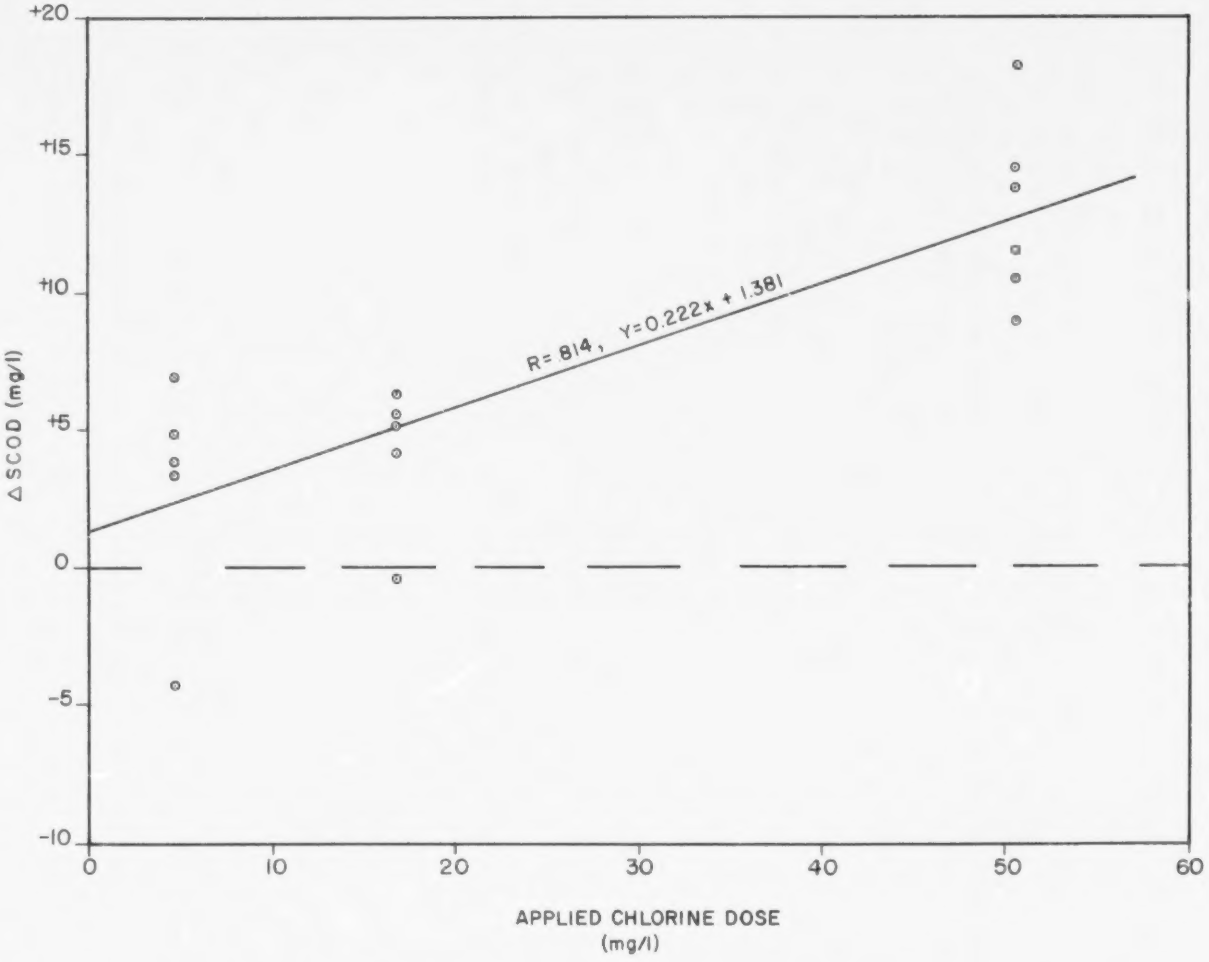


Figure 19. Changes in soluble COD (laboratory data) after a 120 minute contact time, due to addition of chlorine as observed in primary lagoon samples collected on April 9 and 10, 1976. (ΔSCOD = treated minus original SCOD concentration.)

of organic suspended solids (VSS), any discussion of SS holds likewise for VSS. It was found that chlorination of the samples containing high concentrations of algae resulted in a noticeable decrease in SS and an increase in turbidity. This is depicted graphically in Figure 20. In the sample containing low concentrations of algae, there was little noticeable change in either SS or turbidity, as shown in Figure 21. This indicates that changes in SS and turbidity resulting from chlorination are due to the quantity and composition of suspended solids and by the form of chlorine residual. The data suggest that possibly algae are more readily affected by chlorine than are other types of suspended organics.

The observed decrease in SS and increase in turbidity is probably the result of the oxidation of algae cell walls by chlorine, particularly by free chlorine. As algae cells are destroyed, a portion of the suspended solids are converted into soluble organics. Other particles are broken down into many much smaller suspended particles. An increase in the number of particles in suspension results in an increase of light scattering and thus, an increase in turbidity. When samples are filtered using approved filters as prescribed by Standard Methods (1971), some of the very small particles contributing to turbidity may pass through the filters. In this experiment, Whatman GF/C filters were used. The effective pore size of these filters is 1.2 μm. Any particles smaller than that size, which otherwise would contribute to the SS concentration, may pass directly through the filter. This, along with the conversion of suspended solids to completely soluble material, explains the reduction of SS.

In this experiment, the samples were continually mixed in a batch reactor to prevent the reduction of SS as a result of settling. Therefore, all changes in SS concentrations are attributed to the chemical reactions between chlorine and suspended solids. Although the data do not reflect a direct dependence of SS reduction on chlorine dose and residual type, it is reasonable to assume that free chlorine is more significant in reducing SS concentrations than combined chlorine.

FIELD EXPERIMENTS

Reduction of SS by Settling

Upon examination of field data, it was observed that reductions of SS were also accompanied by accumulation of solids in the contact tanks. To determine the proportion of SS reduction attributable to settling, settling tests, as described in Section 5, were performed in August, 1976. The data indicate that most of the SS reduction occurred within five minutes in the contact tanks for the particular quality of secondary effluent treated during the test. For this particular study, suspended solids were composed primarily of *Daphnia* spp. Changes in the SS concentrations due to settling are shown in Figure 22. The reduction of suspended solids was also accompanied by a large accumulation of solids in the bottoms of the contact tanks. The largest accumulations corresponded with the largest reductions of SS. Relative accumulations of solids are shown in Figure 23. It was impossible to perform a mass balance on the data due to the variability of the influent composition during the study.

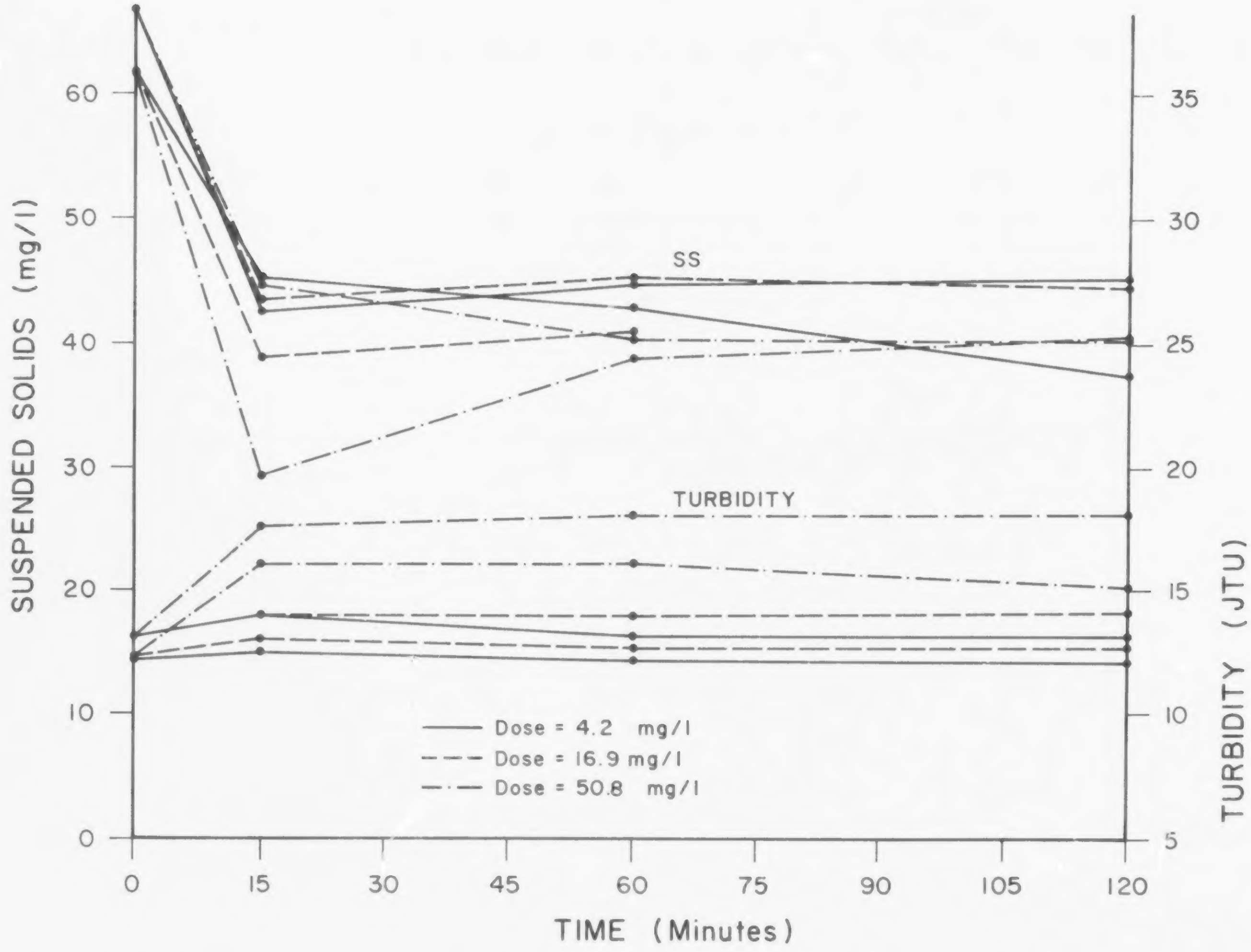


Figure 20. Effects of various chlorine dosages on SS and turbidity of primary lagoon effluent sampled on April 9 and 10, 1976.

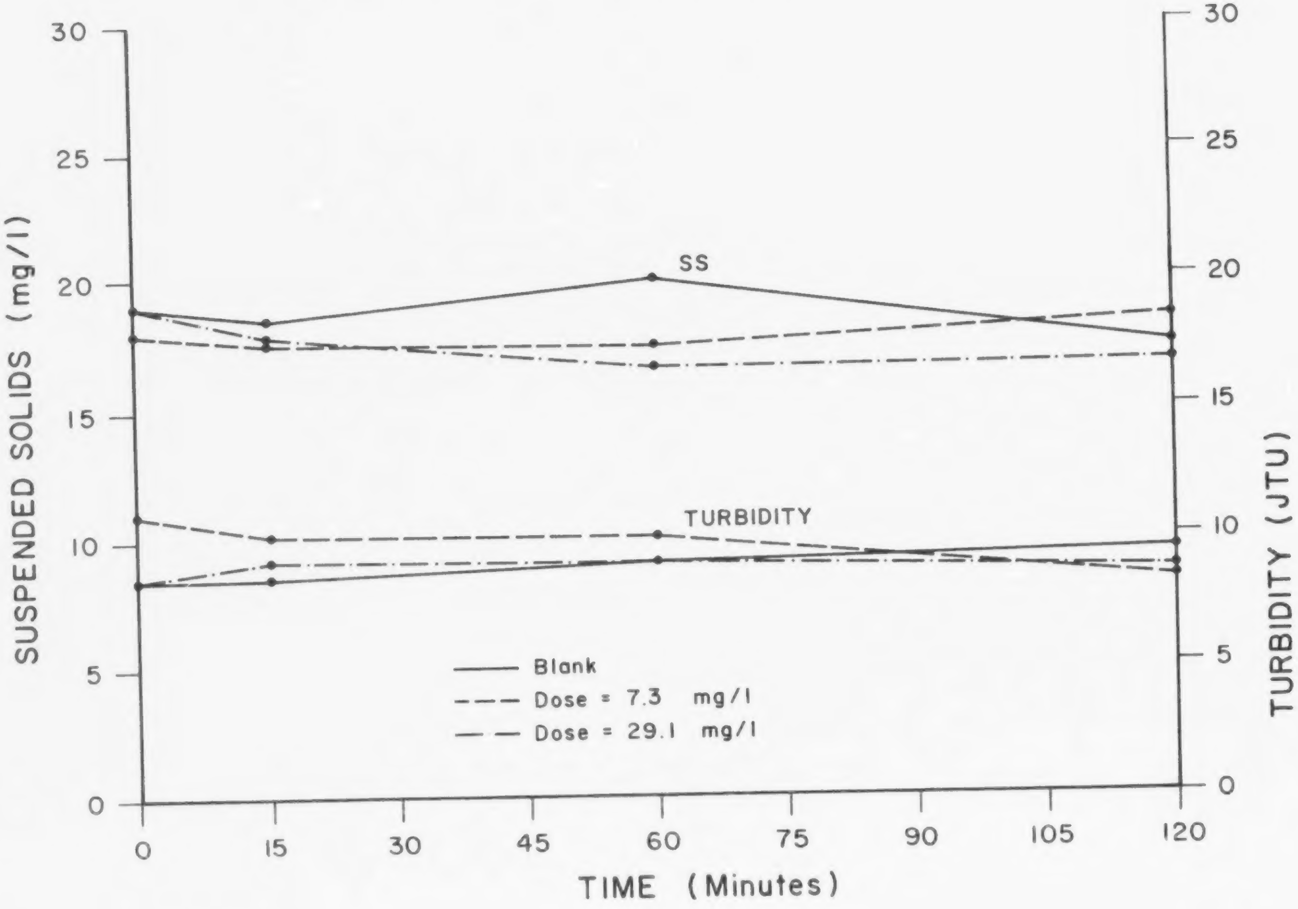


Figure 21. Effects of various chlorine dosages on SS and turbidity of primary lagoon effluent sampled on August 26, 1976.

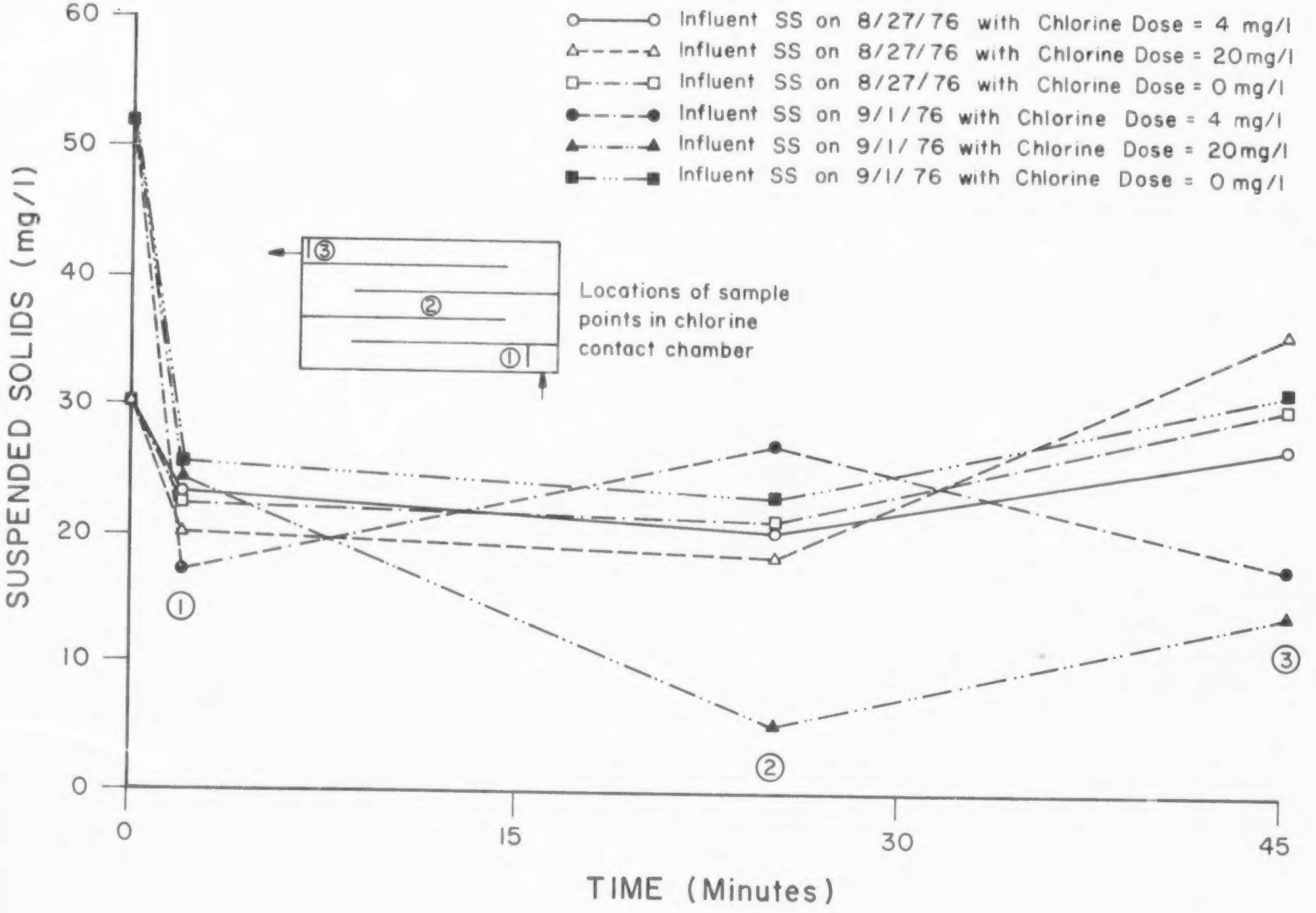


Figure 22. Changes in suspended solids concentrations due to settling within chlorine contact chamber on August 27, 1976, and September 1, 1976.

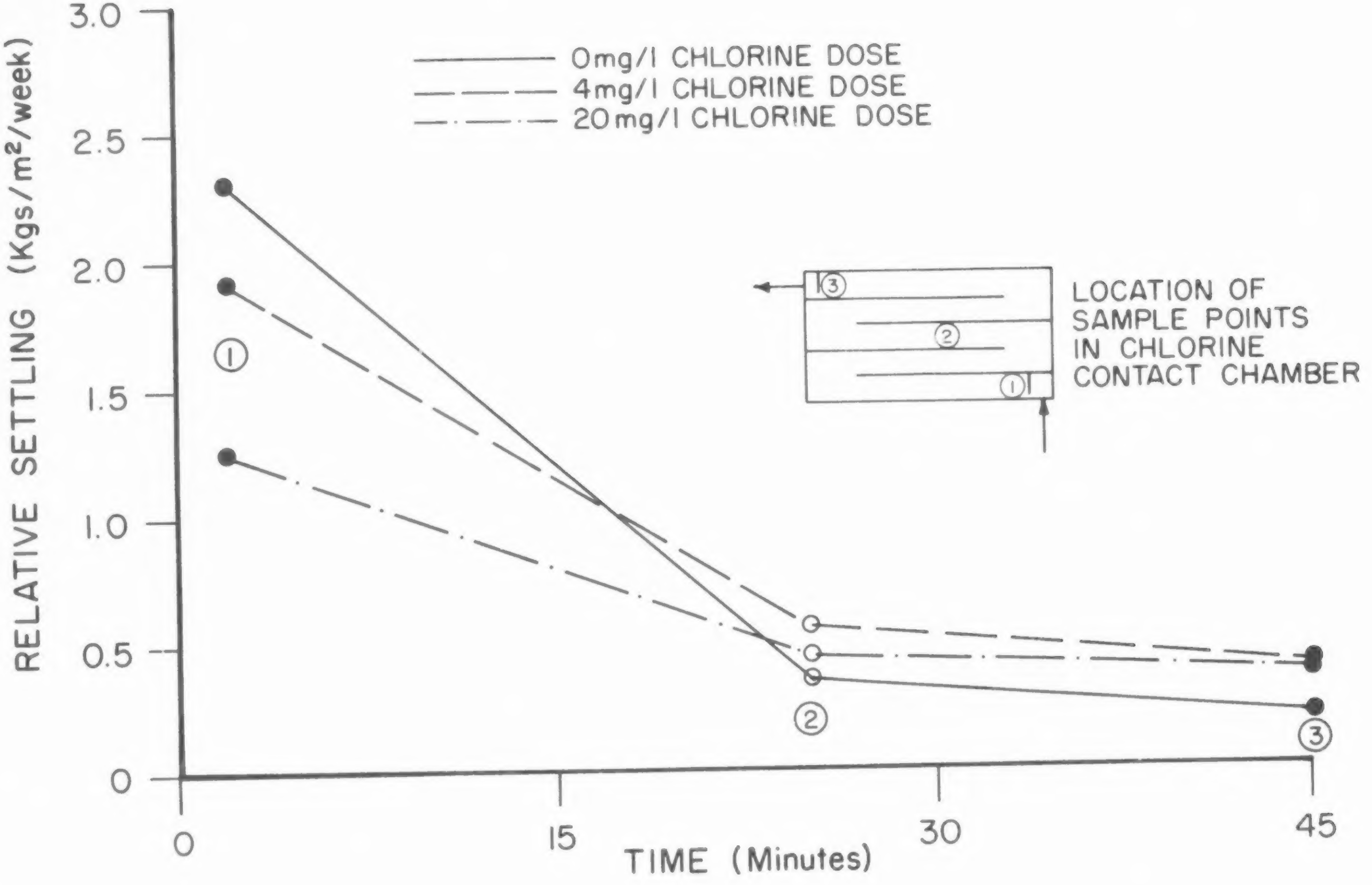


Figure 23. Relative accumulation of solids on the bottom of the chlorine contact chamber due to settling between August 25, 1976, and September 1, 1976.

The data indicate that changes in SS as a result of chemical reactions with chlorine are probably small in comparison with changes resulting from settling. The amount of settling is also highly variable. Inspection of all field data shows that suspended solids reduction varied approximately 10 to 50 percent. The concentration and composition of suspended solids undoubtedly affects the rate of settling. For example, *Daphnia* spp. were observed to settle more readily than algae. Also, the settling velocity of untreated suspended solids is probably more important than chlorine dose in determining the fraction of suspended solids that will settle out within the tank detention time.

Effect of Chlorine on Soluble COD

The field data were analyzed using the same technique applied to the laboratory data in an attempt to establish comparable relationships and verify the laboratory studies. The laboratory results indicated evidence of soluble COD increases with time and chlorine dose (Figures 18 and 19). Figure 24 is a graph of all filtered lagoon effluent data. The figure relates the unchlorinated soluble chemical oxygen demand (control) with the chlorinated or treated soluble COD. The regression line for Figure 24 has a slope slightly greater than one (1.019) but statistical calculations suggest this number is not significantly different from one and hence no apparent overall increase or decrease in soluble COD can be found.

Figure 25 is the same type plot as Figure 24 but with unfiltered lagoon effluent data as the test water. The slope of Figure 25 is less than one (0.978) but, once again, this slope was found not to be statistically different from one, indicating no apparent overall increase or decrease in soluble COD.

To determine if a relationship between unchlorinated soluble organic oxygen demand (control) and chlorinated soluble organic oxygen demand (treated) existed with respect to chlorine dose, the data were grouped according to chlorine dose and analyzed similarly to Figures 24 and 25. However, no significant relationship could be established.

In all cases, the regression analysis was performed by forcing the intercept through the origin because a zero chlorinated SCOD must be equivalent to a zero unchlorinated SCOD when measured on the same influent.

Volatile Suspended Solids Versus Soluble Chemical Oxygen Demand

Since the volatile suspended solids parameter acts as a gross estimate of the total microbial and algal mass, changes in the concentration of VSS may directly affect changes in the SCOD levels due to chlorination. With this in mind, it would be of interest to observe any patterns existing between volatile suspended solids and soluble COD. Of particular concern would be increases or decreases in soluble COD (ΔSCOD) between the unchlorinated and chlorinated (i.e. control and treated) samples with respect to concentrations of volatile suspended solids. Figure 26 (filtered lagoon effluent) and Figure 27 (unfiltered lagoon effluent) illustrate the overall response of ΔSCOD to varying

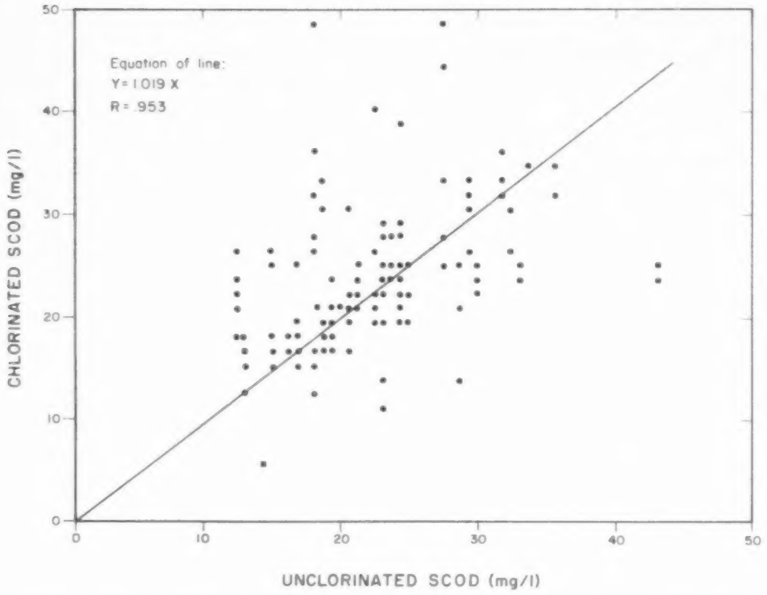


Figure 24. Observed soluble COD in the chlorinated or treated sample with respect to the unchlorinated or control soluble COD using filtered lagoon effluent.

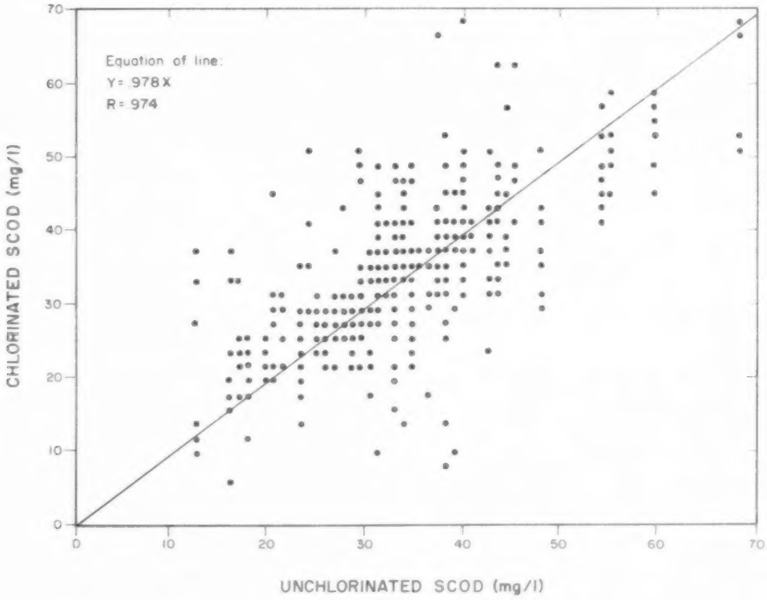


Figure 25. Observed soluble COD in the chlorinated or treated sample with respect to the unchlorinated or control soluble COD using unfiltered lagoon effluent.

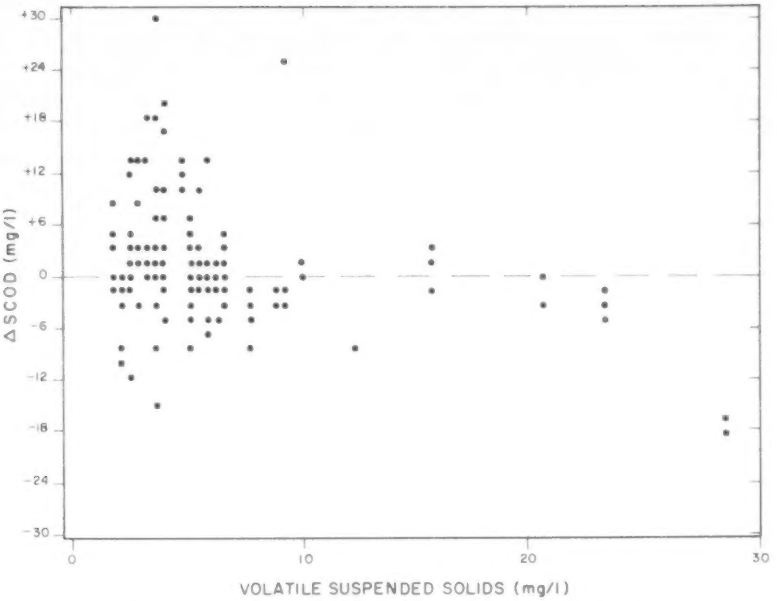


Figure 26. Effects of volatile suspended solids on the changes seen in soluble COD between chlorinated and unchlorinated samples using filtered lagoon effluent. (ΔSCOD = chlorinated minus unchlorinated concentration.)

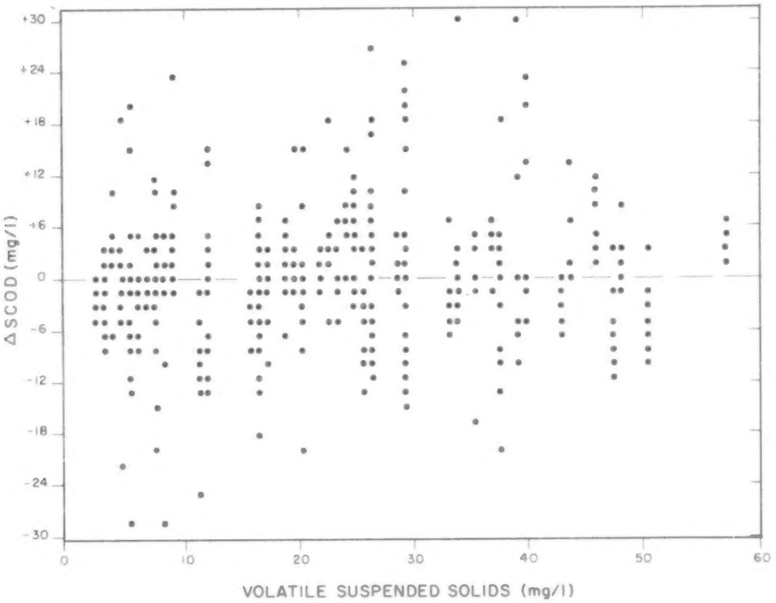


Figure 27. Effects of volatile suspended solids on the changes seen in soluble COD between chlorinated and unchlorinated samples using unfiltered lagoon effluent. (ΔSCOD = chlorinated minus unchlorinated concentration.)

volatile suspended solids concentrations. No distinct pattern of increased or decreased ΔSCOD can be observed in either Figure 26 or 27. This indicates that volatile suspended solids have little effect on observed soluble COD changes when chlorine is applied. Appendix C, Figures C-1 through C-8, contain plots of ΔSCOD versus volatile suspended solids (VSS) concentrations over much narrower ranges of volatile suspended solids (VSS) concentrations (0-5 mg/l, 5-10 mg/l, 10-20 mg/l, 20-30 mg/l, and 30-60 mg/l). These ranges of volatile suspended solids (VSS) concentrations were arbitrarily selected. Again, no distinct pattern can be observed between ΔSCOD and VSS.

Effect of Chlorine Contact Time on Soluble Chemical Oxygen Demand

The effect of chlorine contact time on soluble COD under laboratory conditions is illustrated in Figure 18. This illustration indicates increasing soluble COD concentrations with increasing chlorine contact time. Similar results were not observed when field data for filtered or unfiltered lagoon effluents were treated in a like manner. There is no indication of any change in soluble COD concentration with respect to time in either type lagoon effluent.

Effect of Chlorine Dosage on Soluble Chemical Oxygen Demand

The literature (Echelberger et al., 1971) and laboratory experiments indicate the chlorine dosage is an important parameter which will affect the soluble chemical oxygen demand. As the dosage increases, an increase in soluble COD can be expected. The field data described in Figures 28 and 29 do not express this increase nor is there any indication of a possible decrease in COD. Volatile suspended solids versus ΔSCOD at selected ranges of applied chlorine dosage (0-2 mg/l, and greater than 2 mg/l for filtered lagoon effluent; 0-2 mg/l, 2-4 mg/l, and greater than 4 mg/l for unfiltered lagoon effluent) are depicted in Appendix C, Figures C-9 through C-13. These figures, again, do not indicate any increase or decrease in soluble COD concentration as a result of chlorination, suggesting that chlorine dosage does not produce the same effects on soluble COD in the field as seen in the laboratory.

Chlorine Effects on Volatile Suspended Solids

Figure 30 shows the results obtained when plotting volatile suspended solids concentrations in chlorinated samples versus volatile suspended solids in the original unchlorinated samples. The relationship exhibited in this figure, which is for filtered lagoon effluent only, indicates volatile suspended solids reductions by as much as 35 percent at the higher volatile suspended solids concentrations. Figure 31, unfiltered lagoon effluent data, shows similar results, with the same 35 percent reduction at the high solids concentrations. These reductions are similar to those reported in the literature (Dinges and Rust, 1969). This earlier report suggests volatile suspended solids reductions are due to the destruction of organic solids by the oxidizing power of chlorine. While this explanation may also be true with the field data presented here, it is not unreasonable to assume that a percentage of the volatile suspended solids are simply settling out in the

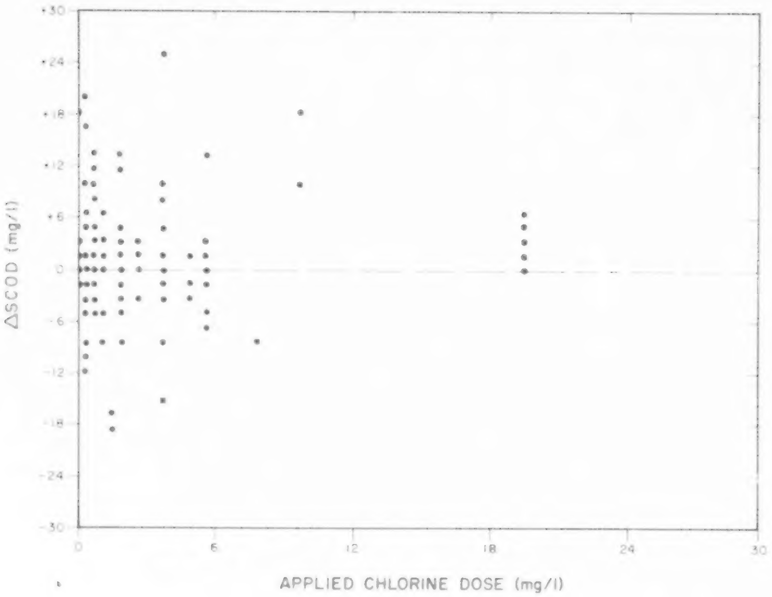


Figure 28. Effects of applied chlorine dosage on the changes seen in soluble COD between treated and untreated samples using filtered lagoon effluent. (ΔSCOD = treated minus untreated concentration.)

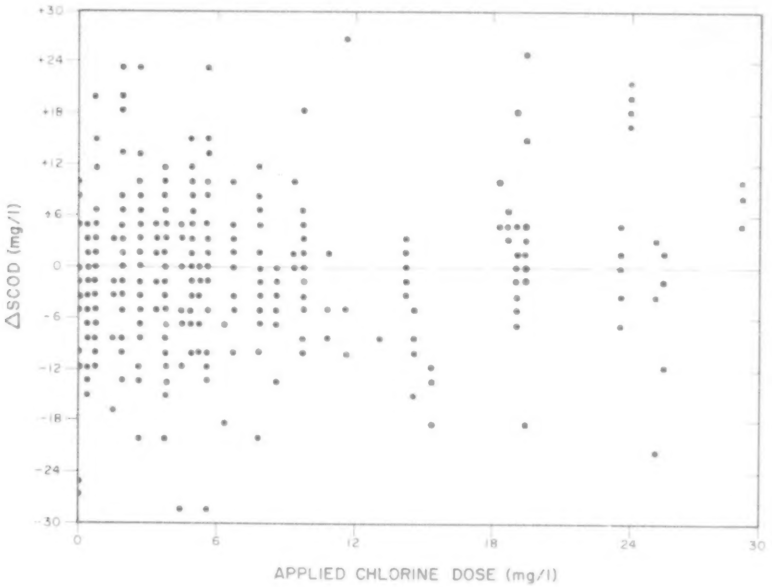


Figure 29. Effects of applied chlorine dosage on the changes seen in soluble COD between treated and untreated samples using unfiltered lagoon effluent. (ΔSCOD = treated minus untreated concentration.)

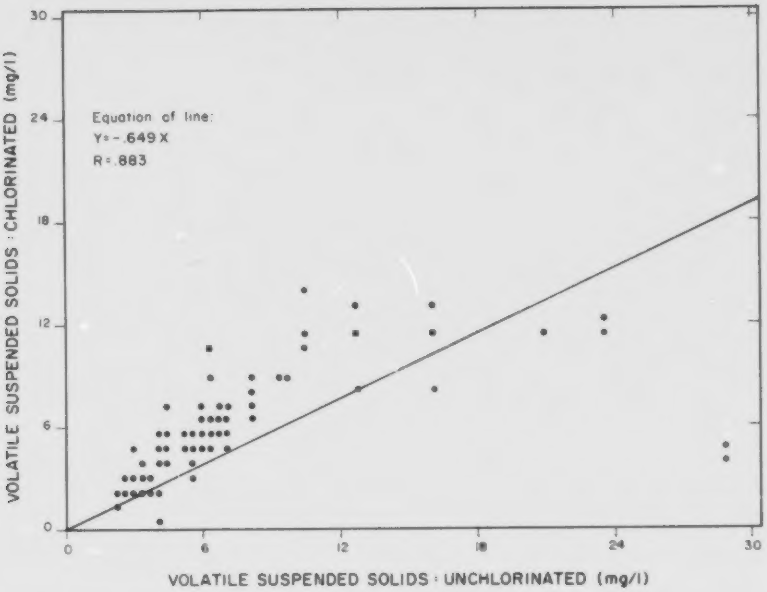


Figure 30. Volatile suspended solids relationships between treated and untreated or chlorinated and unchlorinated samples using filtered lagoon effluent.

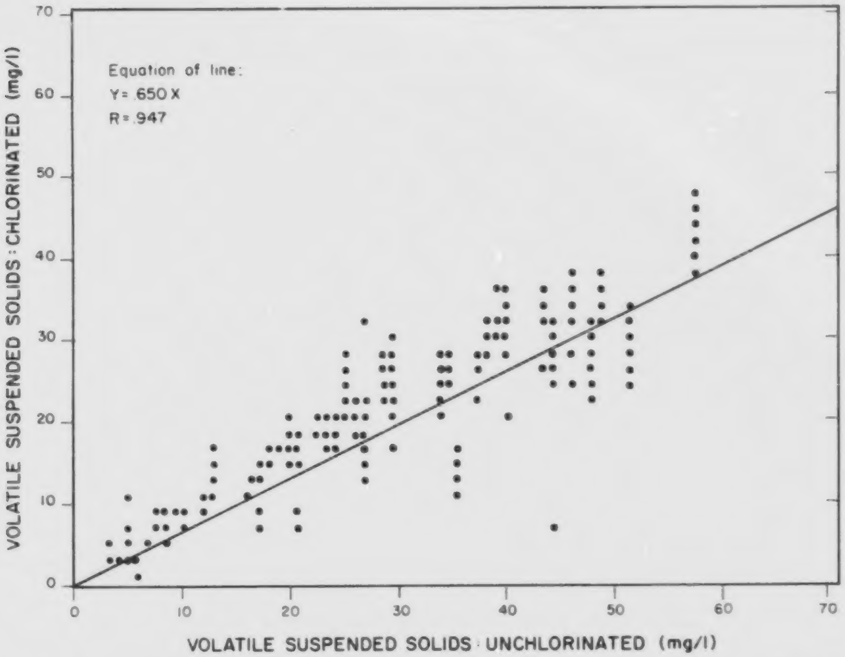


Figure 31. Volatile suspended solids relationships between treated and untreated or chlorinated and unchlorinated samples using unfiltered lagoon effluent.

chlorine contact tanks. This second explanation is in line with the overall indications that there is no apparent increase in soluble COD when chlorine is applied (refer to Figures 24 and 25).

Effect of Free Chlorine Residual on Soluble Chemical Oxygen Demand

Figure 32 shows the effects of free chlorine residual on the changes in soluble COD in unfiltered lagoon effluent. This figure closely resembles the laboratory data of Echelberger et al. (1971), which suggested increased soluble chemical oxygen demand due to chlorine. Thus, it may be possible that the increase in soluble COD in algal laden systems attributed to chlorination may only result when breakpoint chlorination is practiced. It should be noted that this phenomenon was not observed with the filtered lagoon effluent free chlorine residual data. Possible explanations are: a) lower soluble COD concentrations in the control samples, b) fewer data containing free chlorine residual concentrations, or c) reduced suspended solids and subsequent wastewater quality changes in the filtered lagoon effluent.

The results obtained from Figure 32 must be considered with some caution. Careful observation of this graph shows almost as many data points falling below the zero line as above. However, the majority of these points are at lower free chlorine residual levels. Increased soluble chemical oxygen demand is seen almost exclusively at free chlorine residual concentrations greater than 1.8 mg/l, suggesting the trend shown by the regression line in this figure. Laboratory results presented early in this section also indicate free chlorine residual may be causing the increase in soluble COD. The statement

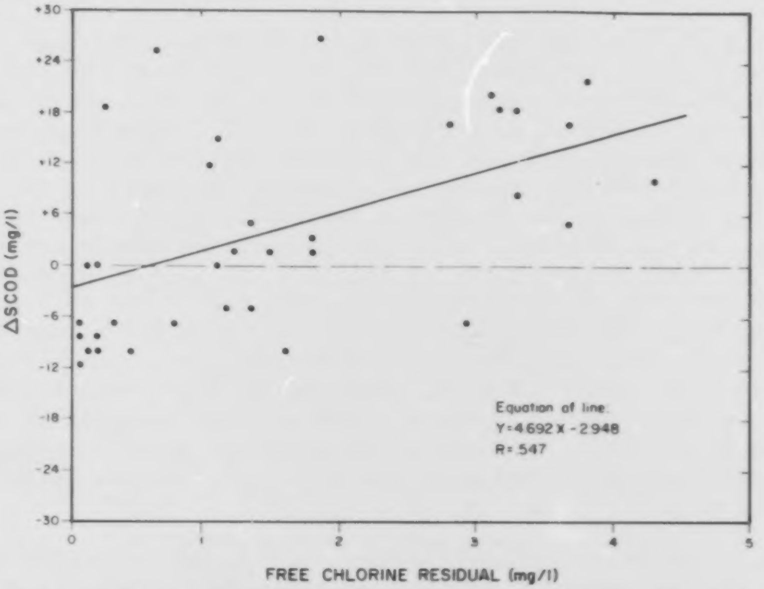


Figure 32. Changes in soluble COD when free chlorine residual is present in unfiltered lagoon effluent.

made above that increases in soluble COD in algal laden systems due to chlorination may be the result of free chlorine residual concentration is based on these observations.

Using the unfiltered lagoon effluent free chlorine residual data and testing to determine if greater volatile suspended solids reductions could be observed added little information to the volatile suspended solids reductions discussed earlier. Results of this test (refer to Figure C-14 in Appendix C) indicated no increases in volatile suspended solids reductions over those reported in Figures 30 and 31. This suggests that volatile suspended solids reductions are not affected by free chlorine residual concentration to any significant level from those reductions observed with total chlorine residual present. A further comparison of these free chlorine residuals with combined chlorine residual effects on volatile suspended solids also indicated no contrasting information.

The similar effects that chlorine residual species have on volatile suspended solids reduction may further add to the idea that volatile suspended solids are simply settling out in the chlorine contact tanks as suggested earlier.

Effects of Chlorination on Coliform Reduction

General--

The most probable number technique (MPN) for the measurement of coliform bacteria concentrations was used throughout this study. This analysis was employed because it is generally accepted by most researchers and because of the reduced possibility of chemical and biological interferences (APHA, 1971).

Several of the coliform data indicated inconsistencies when related to chlorine contact time and dose. The inconsistencies were in the form of increased coliform concentrations reported at the 50 minute chlorine contact time from those concentrations reported at the 35 minute chlorine contact time within the same contact tank and for the same applied chlorine dose. It was found that the problem was related to the method of sample collection. Samples were collected at the 18 and 35 minute chlorine contact times with a siphoning apparatus, while the 50 minute chlorine contact time sample was collected directly from the discharge pipe. A change to the siphoning apparatus for all samples corrected the inconsistency. A correction of the inconsistent data was performed using the lower limits of the MPN confidence interval. These corrected coliform data appeared to be more consistent with the data collected using the siphoning apparatus at the earlier chlorine contact times (i.e. no increase in coliform concentration over those data collected at the earlier chlorine contact times). The results obtained by using the siphoning apparatus for all chlorine contact times were similar to the results obtained when using the corrected data.

Because of the above indicated consistencies, the corrected data have been substituted for the original data and are reported in Appendix A, Table A-1. An asterisk prior to the sample month indicates corrected data. There are 1,804 pieces of coliform data listed in this appendix, of which 93 have been corrected. This represents 5.2 percent of the total coliform information collected. It is felt that the inclusion of this small amount of corrected data in the total data analysis for coliform reduction will not significantly bias the results.

To determine disinfection efficiency (with respect to both total and fecal coliforms) as a function of total chlorine residual, the data were fitted with a linear regression equation, which expresses the logarithm of the fraction of coliform remaining as a function of total chlorine residual. The results of this analysis are reported in Appendix D, Figures D-1 to D-16. The intercept values for these regression equations range from -0.3 to -1.3, indicating that a zero total chlorine residual concentration will produce a coliform reduction of from 50 percent to 95 percent. This does not agree with reports in the literature (Butterfield, 1943; Fair et al., 1968; Hom, 1972; Metcalf and Eddy, Inc., 1972). A possible explanation for this anomaly is that chlorine combined with ammonia, organic materials, sulfides, and other compounds and thus dissipates leaving no measurable chlorine residual. However, at some point in time (perhaps only an instant after addition) the chlorine is also in contact with the bacteria in the water and available for disinfection, resulting in decreases in coliform concentrations indicated by the intercept values. The intercept values may also be due to the statistical confidence intervals associated with the MPN values.

In an attempt to relate the results of this study with those reported in the literature (Butterfield, 1943; Fair et al., 1968; Hom, 1972; Metcalf and Eddy, Inc., 1972) a similar regression analysis as discussed above was performed using a forced zero intercept (Hurst, undated a,b). The results of this analysis are illustrated in the discussion presented later in this chapter. The correlation coefficients were significant at the 5 percent level for all reported regression equations. Because of this high degree of statistical significance, the forced zero intercept regression analysis was used in discussing the results in this section.

The effect of total chlorine residual on total and fecal coliform density for filtered and unfiltered lagoon effluent are shown in Figures 33 through 48. These results are expressed as the $\log_{10} N/N_o$ (in which N = the number of organisms per 100 ml after chlorination, and N_o = the original number of organisms per 100 ml), or the logarithm of the fraction remaining after chlorination versus varying concentrations of total chlorine residual.

Filtered Lagoon Effluent--

Total coliform reduction--The effect of total chlorine residual on total coliform numbers after chlorine contact times of 18, 35, and 50 minutes using filtered lagoon effluent is reported in Figures 33 through 35. These figures were constructed using the data obtained from the total coliform analysis of the MPN determination. For discussion purposes, Figures 33 through 35 have been summarized in Figure 36. Analysis of Figure 36 indicates that the rate of total coliform removal increases with increasing total chlorine residual. This result is in agreement with reports in the literature (Butterfield, 1948; Chambers, 1971; Green and Stumpf, 1944; Hom, 1970; Kott, 1971; White, 1972). Results from Figure 36 indicate that a total coliform organism

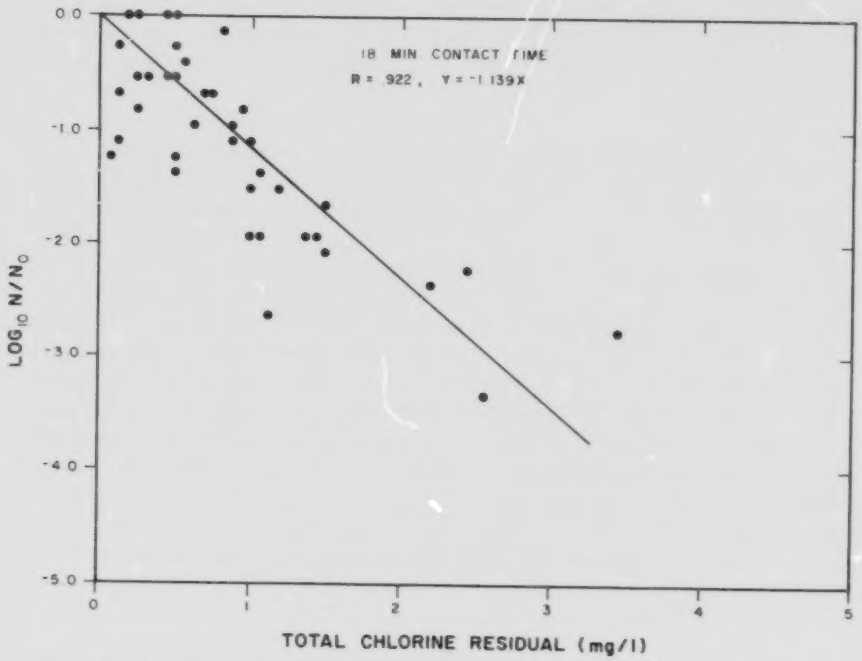


Figure 33. Total coliform reduction in filtered lagoon effluent as a function of total chlorine residual after 18 minutes contact time.

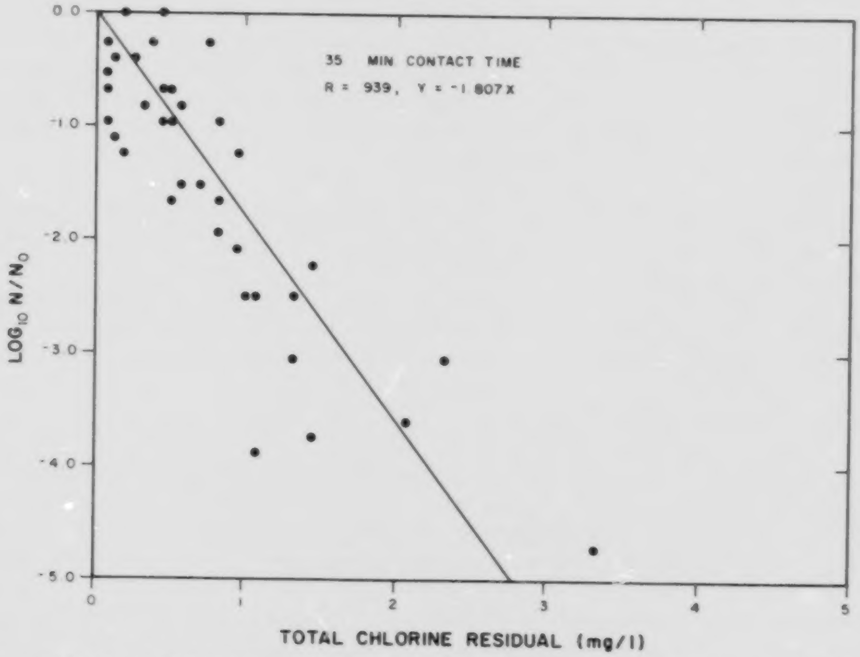


Figure 34. Total coliform reduction in filtered lagoon effluent as a function of total chlorine residual after 35 minutes contact time.

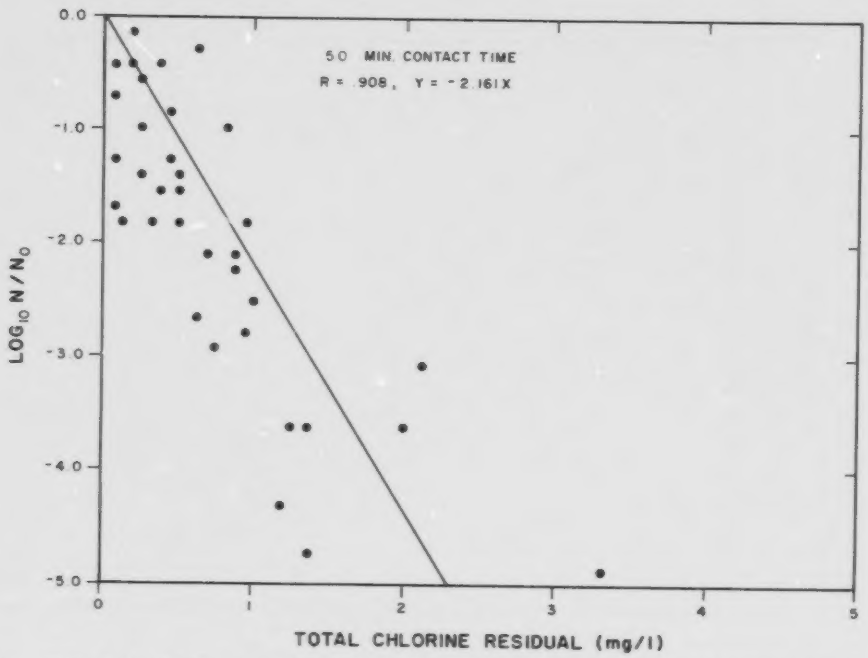


Figure 35. Total coliform reduction in filtered lagoon effluent as a function of total chlorine residual after 50 minutes contact time.

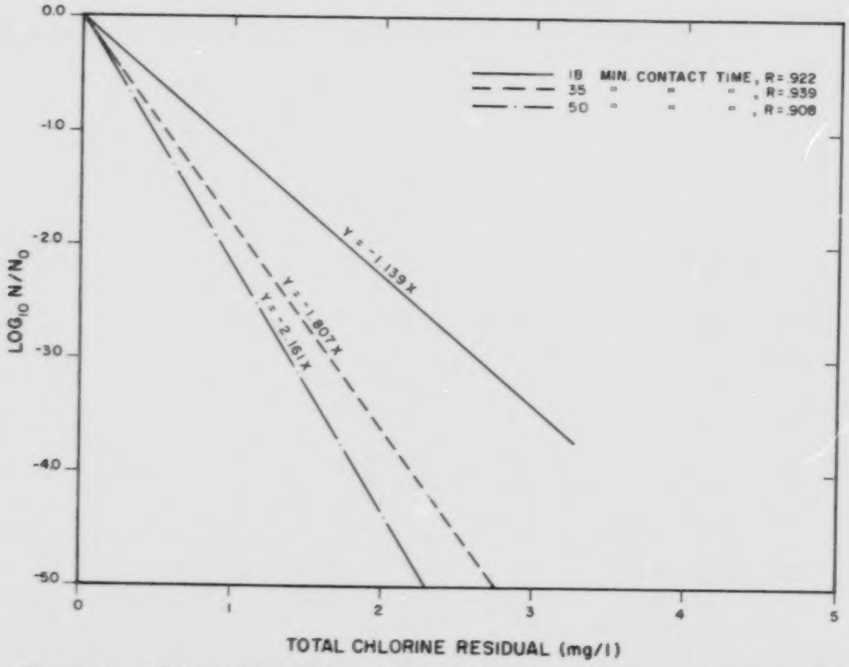


Figure 36. Summary of total coliform removal efficiency in filtered lagoon effluent as a function of total chlorine residual at various chlorine contact times.

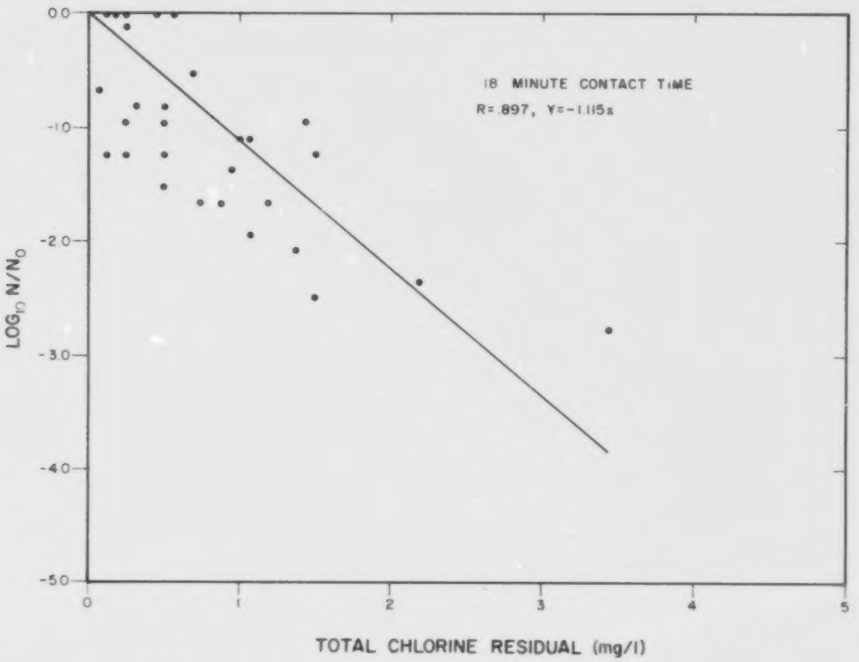


Figure 37. Fecal coliform reduction in filtered lagoon effluent as a function of total chlorine residual after 18 minutes contact time.

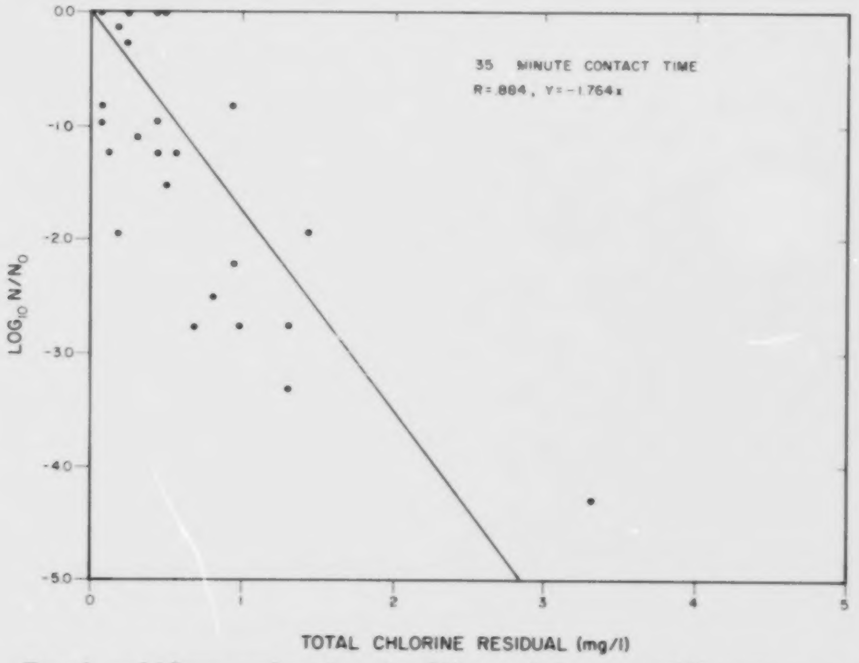


Figure 38. Fecal coliform reduction in filtered lagoon effluent as a function of total chlorine residual after 35 minutes contact time.

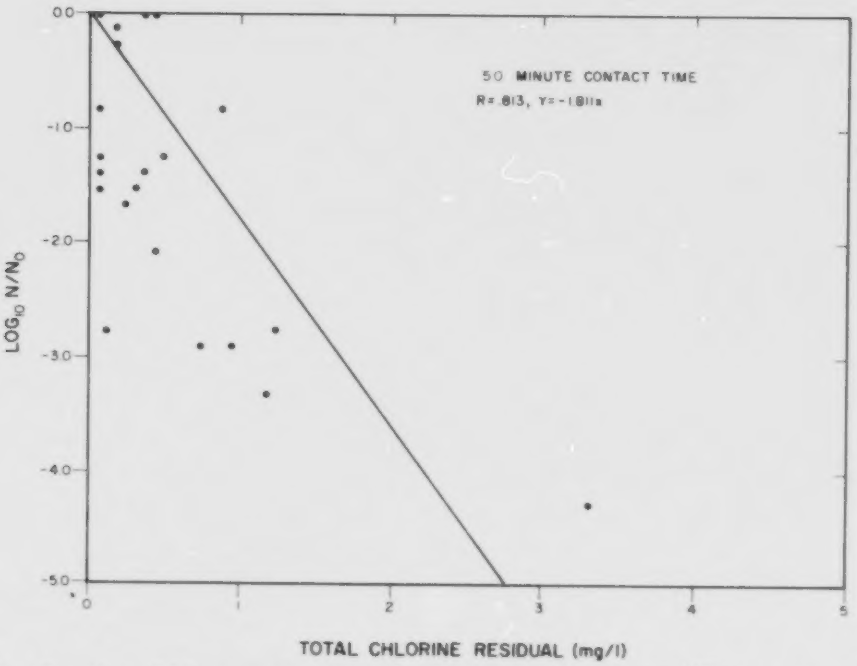


Figure 39. Fecal coliform reduction in filtered lagoon effluent as a function of total chlorine residual after 50 minutes contact time.

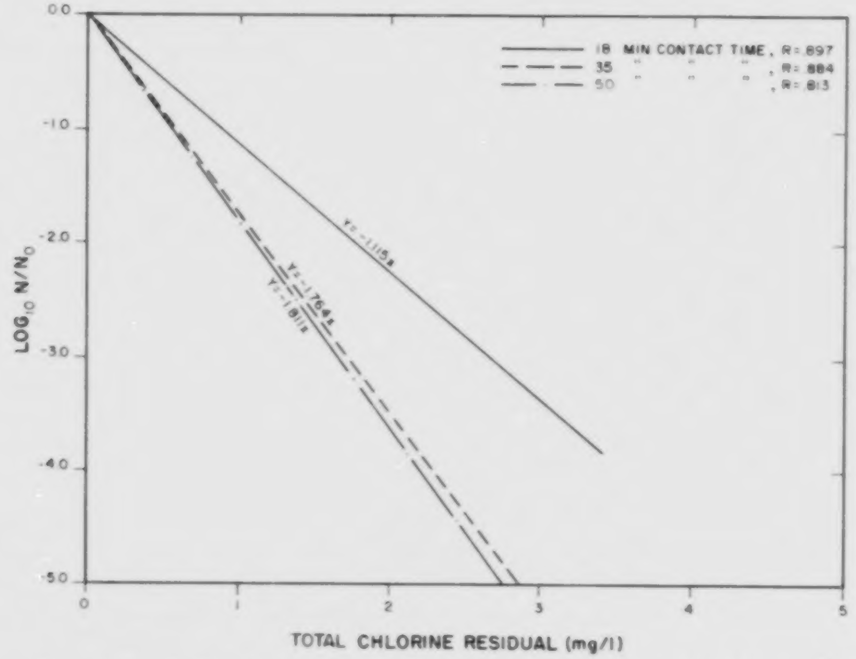


Figure 40. Summary of fecal coliform removal efficiency in filtered lagoon effluent as a function of total chlorine residual at various chlorine contact times.

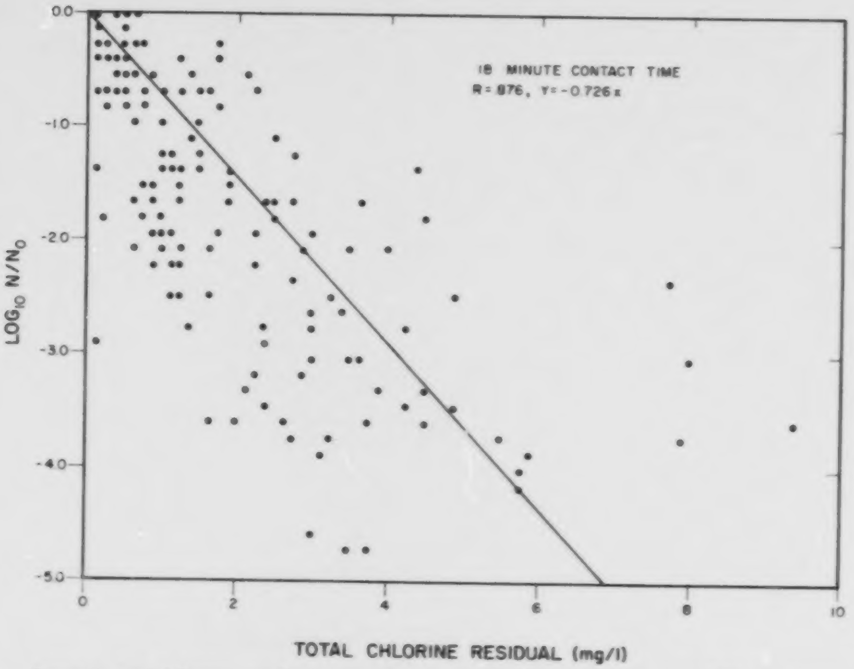


Figure 41. Total coliform reduction in unfiltered lagoon effluent as a function of total chlorine residual after 18 minutes contact time.

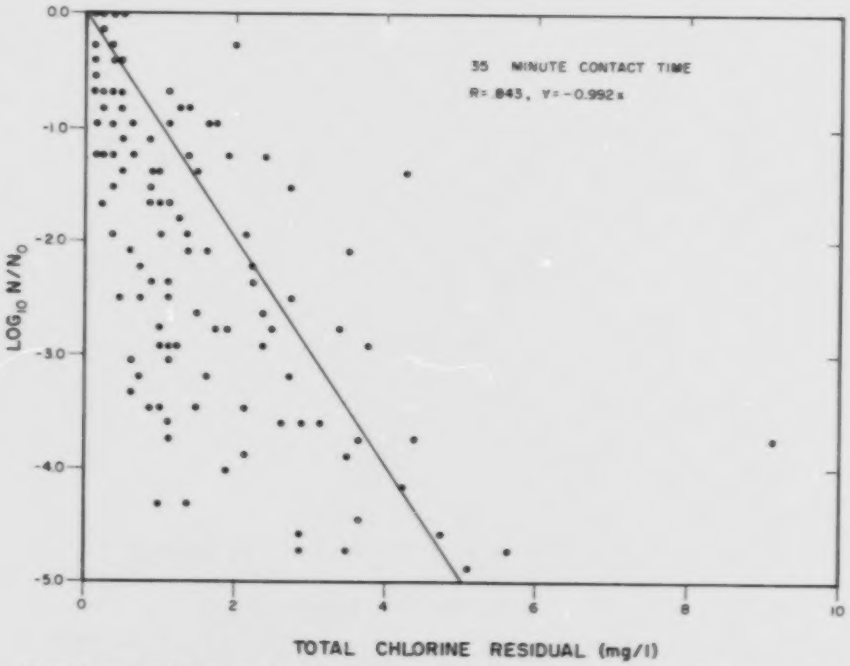


Figure 42. Total coliform reduction in unfiltered lagoon effluent as a function of total chlorine residual after 35 minutes contact time.

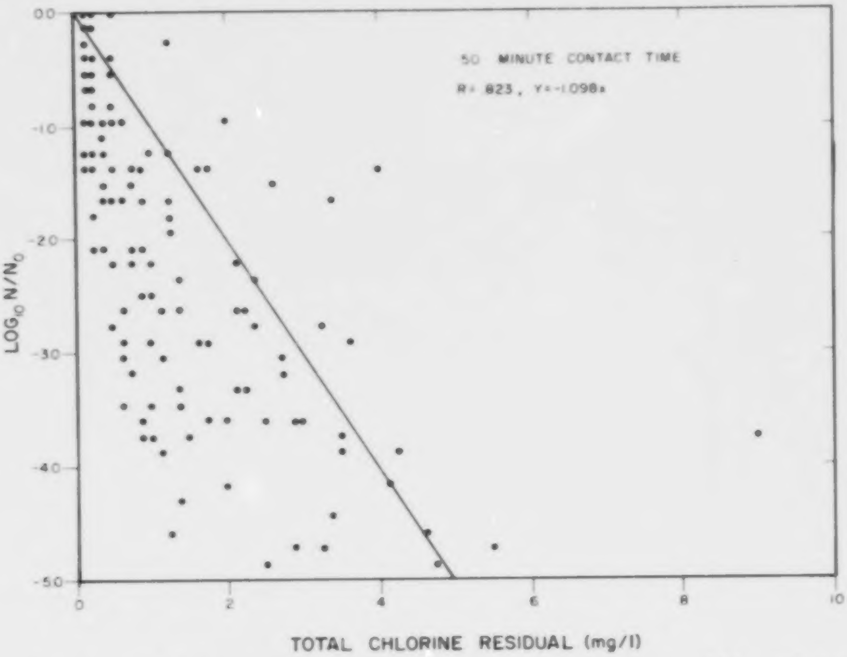


Figure 43. Total coliform reduction in unfiltered lagoon effluent as a function of total chlorine residual after 50 minutes contact time.

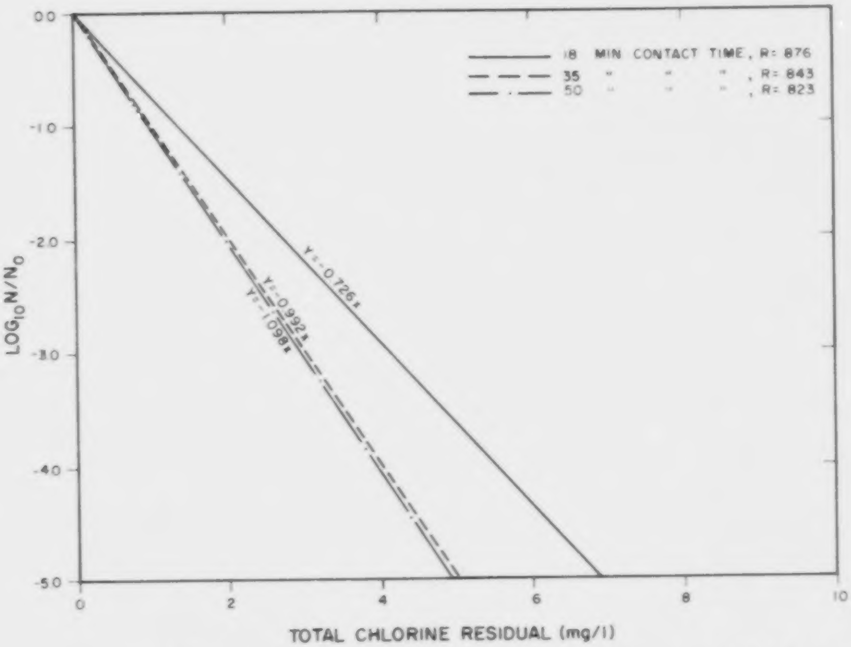


Figure 44. Summary of total coliform removal efficiency in unfiltered lagoon effluent as a function of total chlorine residual at various chlorine contact times.

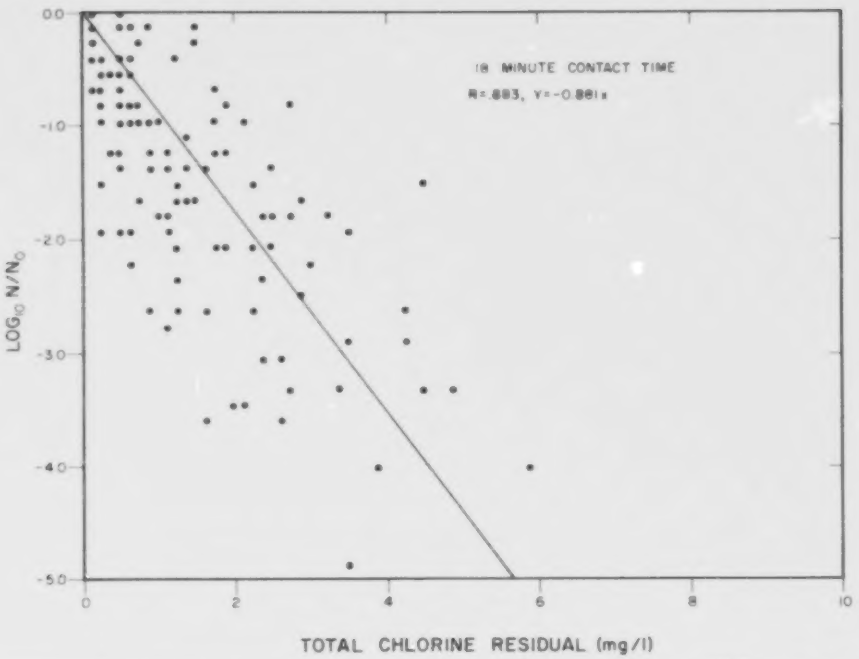


Figure 45. Fecal coliform reduction in unfiltered lagoon effluent as a function of total chlorine residual after 18 minutes contact time.

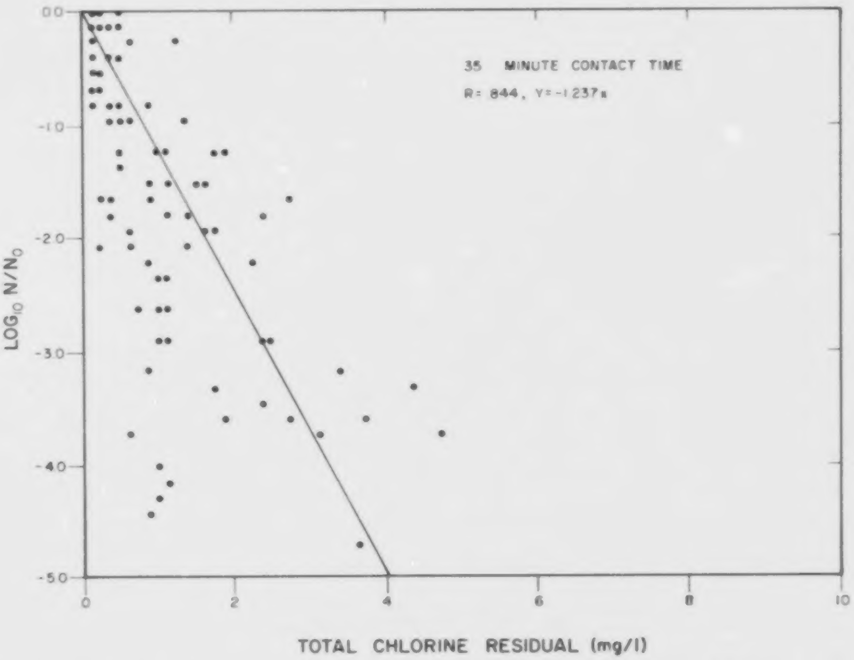


Figure 46. Fecal coliform reduction in unfiltered lagoon effluent as a function of total chlorine residual after 35 minutes contact time.

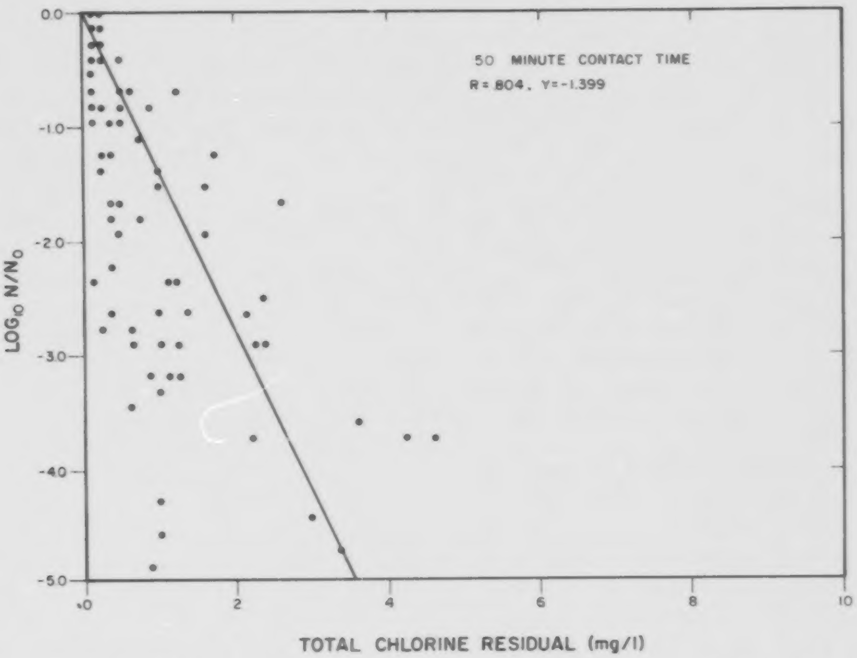


Figure 47. Fecal coliform reduction in unfiltered lagoon effluent as a function of total chlorine residual after 50 minutes contact time.

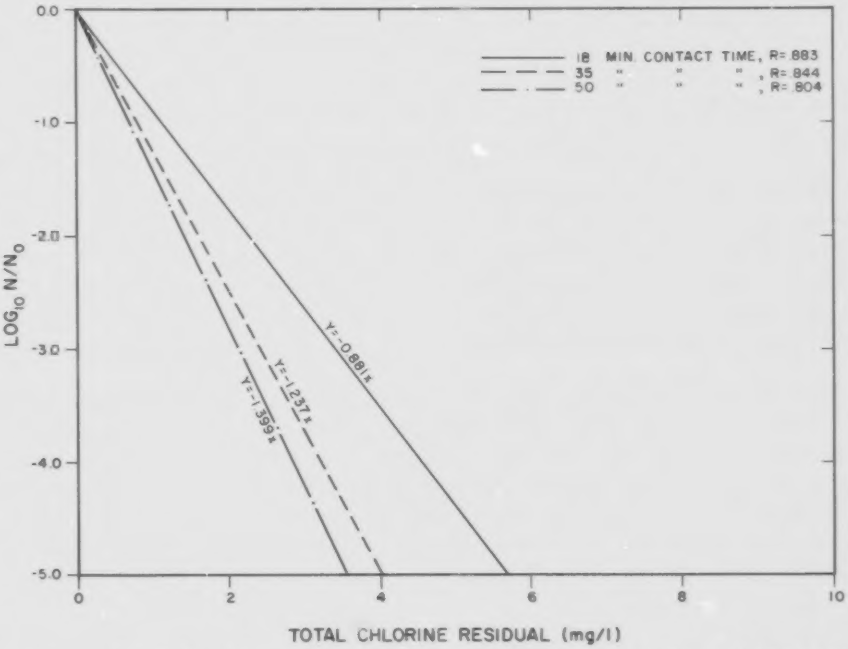


Figure 48. Summary of fecal coliform removal efficiency in unfiltered lagoon effluent as a function of total chlorine residual at various chlorine contact times.

reduction of 99.9 percent in filtered lagoon effluent can be expected with a total chlorine residual concentration of 2.7 mg/l after 18 minutes chlorine contact time. The 99.9 percent level of reduction was chosen for discussion because at this removal efficiency the data and subsequent regression lines are well developed and interpretation of results is accomplished with less inference.

By using a statistical test which employs sums of squares, sums of products, degrees of freedom, sample regression coefficients, and regression equation slopes (Steel and Torrie, 1960), it was determined that the slopes of the regression equations for the 35 and 50 minute chlorine contact times reported in Figure 36 were not significantly different from one another and could be regarded as having the same slope. This statistical procedure is used in determining whether confidence intervals for two regression lines overlap. If an overlap does occur, it is an indication that the regression equations (regression lines) are not statistically different. Statistical results of this kind further suggest that the two regression lines describe a range in which a single regression line would be found. Therefore, if the data for both the 35 and 50 minute chlorine contact times were analyzed together and fitted with a regression equation, the line described by this equation would fall somewhere between the 35 and 50 minute chlorine contact time regression lines shown in Figure 36. However, this approach was not used because it was apparent that to group two different operational time period data would be statistically incorrect. Because these two regression lines are not significantly different and because grouping data is invalid, interpolation between the 35 and 50 minute chlorine contact time regression lines in Figure 36 indicate that a total chlorine residual of 1.5 mg/l is required to produce a 99.9 percent total coliform reduction at chlorine contact times between 35 and 50 minutes. This concentration is contrasted with the 2.7 mg/l total chlorine residual needed for the same level of reduction at the 18 minute chlorine contact times, which is consistent with earlier reports (Butterfield, 1948; Chambers, 1971; White, 1972).

The above experimental and statistical results imply that an increase in chlorine contact time from 18 to 35 minutes will require 1.2 mg/l or 44 percent less total chlorine residual to obtain the same level of total coliform destruction. However, at chlorine contact times between 35 and 50 minutes, there is no statistically significant difference in total chlorine residual required to produce a 99.9 percent reduction in total coliform concentration.

The consistency of this latter observation is confirmed in Figures 40, 44, and 48. These figures summarize the disinfection data for total and fecal coliforms versus total chlorine residual in both filtered and unfiltered lagoon effluent. A possible explanation for this affect occurring consistently at the 35 and 50 minute chlorine contact time is that coliform concentrations are reduced to such low levels within the 35 minute chlorine contact time that further reductions with increasing time are not statistically measurable.

Fecal coliform reduction--The effects of total chlorine residual on fecal coliform bacteria in filtered lagoon effluent are illustrated in Figures 37-39 at 18, 35, and 50 minutes of chlorine contact time, respectively. Figure 40 is a summary of Figures 37-39. This figure depicts a trend in reduction of fecal coliform levels with increasing total chlorine residual concentration and chlorine contact time similar to the trend indicated by Figure 36 for total coliform reduction. The 35 and 50 minute chlorine contact time regression lines for Figure 40 were also found to have statistically similar slopes. An average of 1.7 mg/l total chlorine residual after 35 to 50 minutes contact time is needed to effect a three log fecal coliform reduction. At the 18 minute chlorine contact time, 2.7 mg/l total chlorine residual were required to reduce fecal coliform bacteria to this same level. This is a difference of 1.0 mg/l or 37 percent less total chlorine residual. This suggests longer chlorine contact times will produce the same level of fecal coliform removal as higher total chlorine residual concentrations. Again, these results are similar to earlier published reports (Chambers, 1971; Hom, 1970; White, 1972).

Unfiltered Lagoon Effluent--

Total coliform reduction--Figures 41 through 48 relate the response of unfiltered lagoon effluent coliform concentrations to total chlorine residual. Total coliform reduction versus residual chlorine at three different contact times (18, 35, and 50 minutes) is illustrated in Figures 41-43. A summary of these three figures is presented in Figure 44. Figure 44 indicates, again, that increasing amounts of total chlorine residual and chlorine contact time will increase the reduction of total coliform concentration. This summary graph (Figure 44) indicates that a 99.9 percent reduction of total coliform bacteria can be achieved with 18 minutes of chlorine contact at total chlorine residual concentrations of 4.2 mg/l. The regression lines in this figure illustrating the 35 and 50 minute chlorine contact times are statistically the same for reasons discussed earlier, in connection with filtered lagoon effluent, and suggest that an average of 3.0 mg/l total chlorine residual is required to reduce total coliform concentrations by 99.9 percent at these chlorine contact times. This is a 29 percent, or 1.2 mg/l, reduction of total chlorine residual for the 35 to 50 minute chlorine contact times over that for the 18 minute chlorine contact time.

Fecal coliform reduction--The effect of total chlorine residual on fecal coliform reduction in unfiltered lagoon effluent is shown by Figures 45-47 for chlorine contact times of 18, 35, and 50 minutes, respectively. These results are summarized in Figure 48. Figure 48 indicates reduced fecal coliform concentrations with increased chlorine contact time and total chlorine residual. A 3.4 mg/l total chlorine residual with an 18 minute chlorine contact time and an average of 2.3 mg/l of total chlorine residual for 35 and 50 minutes chlorine contact times is suggested by this figure to reduce fecal coliform levels by 99.9 percent. This means 32 percent less total chlorine residual is required at the longer contact times than for that at 18 minutes chlorine contact to produce the same level of reduction.

Results obtained from the unfiltered lagoon effluent fecal coliform data indicate that the 99.9 percent reduction levels are achieved at lower concentrations of total chlorine residual than for total coliform reduction in unfiltered lagoon effluent (an average of 5.7 mg/l total chlorine residual for fecal coliform compared to 7.2 mg/l total chlorine residual for total coliform, or 21 percent less). Fecal coliform bacteria may be less resistant to chlorine in unfiltered lagoon effluent. The different wastewater characteristics from those of filtered lagoon effluent in combination with chlorine may cause the fecal coliform to die-off at a greater rate in the unfiltered lagoon effluent. This reason may help to explain why total chlorine residual concentrations vary in effectiveness between total and fecal coliform reduction with unfiltered lagoon effluent and not with filtered lagoon effluent.

Summary--

Results indicate that increasing total chlorine residual will produce increased total and fecal coliform reduction for both filtered and unfiltered lagoon effluent. Results also suggest that statistically significant reductions in coliform concentration can be accomplished at the same residual chlorine level with increasing chlorine contact times.

Indications are that less total chlorine residual is required for disinfection of filtered lagoon effluent over that of unfiltered lagoon effluent. An average of 3.6 mg/l total chlorine residual is required for a 99.9 percent reduction of total coliform numbers in unfiltered lagoon effluent, while only 2.1 mg/l is needed for the same reduction in filtered lagoon effluent, a 42 percent lower chlorine residual requirement. In addition, 23 percent less total chlorine residual (2.2 mg/l) is required to achieve a 99.9 percent reduction of fecal coliform numbers in filtered lagoon effluent, as compared with unfiltered lagoon effluent (2.85 mg/l).

There is also evidence that fecal coliform bacteria in unfiltered lagoon effluent are reduced to the 99.9 percent level with smaller concentrations of total chlorine residual than are the total coliform bacteria.

Factors Affecting Chlorine Residual

General--

As discussed in the literature review section, the chlorine demand is affected by many different wastewater characteristics. Among these are volatile suspended solids, ammonia, and temperature. These parameters are important because of their effect upon disinfection practices and also because of resultant effects that chlorination has on ammonia and volatile suspended solids.

Effects of applied chlorine dose on
total chlorine residual--

The overall relationships found between the applied chlorine dosage and the observed total chlorine residual for all chlorine contact times studied (i.e., 18 min, 35 min, and 50 min) and for filtered and unfiltered lagoon effluent are described by Figures 49 and 50, respectively. The difference between the applied chlorine dose and the total chlorine residual is the chlorine demand. Both figures (regardless of lagoon effluent type) indicate similar results. They suggest an expected total chlorine residual of about one-half the applied chlorine dose. Therefore, about one-half of the chlorine is being taken up by materials that create a chlorine demand. These results are comparable to the results reported in the literature on other types of

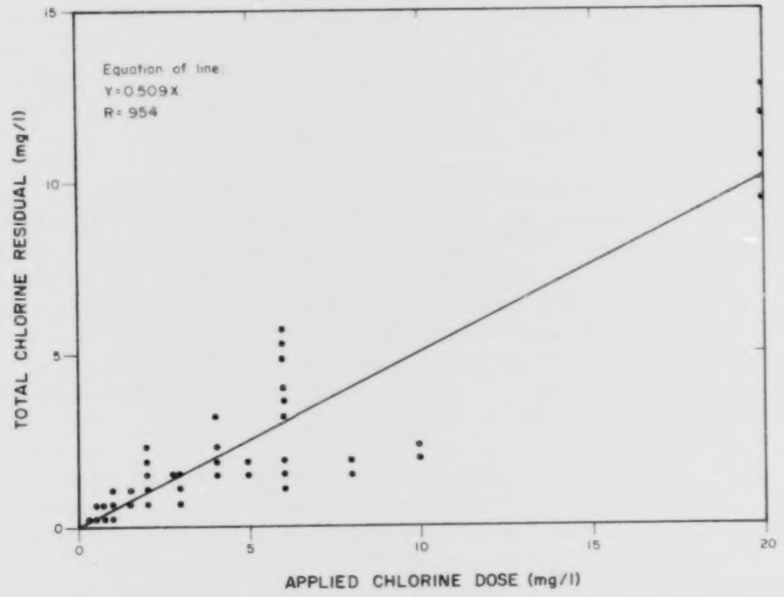


Figure 49. Observed total chlorine residual remaining versus chlorine dosage for chlorine contact times of 18, 35, and 50 minutes using filtered lagoon effluent.

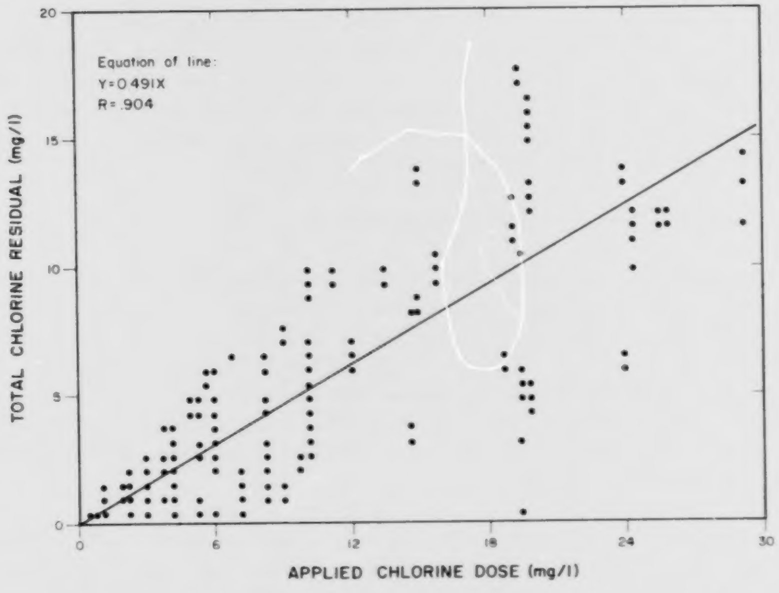


Figure 50. Observed total chlorine residual remaining versus chlorine dosage for chlorine contact times of 18, 35, and 50 minutes using unfiltered lagoon effluent.

secondary treated wastewater (Durham and Wolf, 1973; Echelberger et al., 1971; Eliassen and Krieger, 1950; Hom, 1970; Kott, 1971; Laubusch, 1962). However, the typical lag in the chlorine demand curve is not illustrated by the data, because chlorine residual was measured after a specified contact time (i.e., 18 min, 35 min, or 50 min).

The relationship between applied chlorine dose and observed total chlorine residual at various chlorine contact times using filtered lagoon effluent is illustrated in Figures 51-53 and summarized in Figure 54. Statistical comparison of the slopes of the regression lines indicates no difference at the 5 percent level of significance, and, therefore, these regression lines are considered to have the same slope. Thus, regardless of the contact time, the chlorine residual was always approximately one-half the total applied chlorine dose, suggesting that very little residual die-away occurred in the chlorine contact chamber.

In Figures 55 to 57, similar data from unfiltered lagoon effluent are presented. Figure 58 is a composite of those data. Statistical analysis indicates that the slopes of the regression lines which describe the data at the various chlorine contact times are not significantly different. Thus, the chlorine demand in unfiltered lagoon effluent was constant regardless of chlorine dosage and contact time.

Effects of volatile suspended solids on chlorine residual--

The literature suggests that organic solids exert a moderate chlorine demand (Snow, 1952; Wallace and Tiernan, undated). It follows, therefore, that large concentrations of volatile suspended solids, which are an index of organic solids, would create a high chlorine demand. A statistical plotting method (Hurst, undated a) was employed to find ranges of volatile suspended solids, in both the filtered and unfiltered lagoon effluent, that would indicate a relationship with total chlorine residual concentration. Results of this analysis were inconclusive and, therefore, are not included in this section (see Appendix C, Figures C-15 to C-24).

Effects of ammonia on chlorine demand--

The reactions between chlorine and ammonia (NH_3-N) in wastewater are important because chloramines are less effective disinfectants than free available chlorine (McKee et al., 1960; Weber, 1972). The chlorine breakpoint curve, as shown in Figure 1, describes the resulting chlorine residual concentrations with increasing chlorine dose at various mole ratios of Cl_2:NH_3-N. As the molar ratio of Cl_2:NH_3-N exceeds 1.0, further increases in applied chlorine dose result in a marked decrease in titrable chlorine residual.

An adaptation of Figure 1 is illustrated in Figure 59 and indicates the chlorine demand (applied Cl_2 dose minus total Cl_2 residual) at various mole ratios of Cl_2 to NH_3. A constantly increasing slope is suggested by Figure 59 with the greatest incline occurring between the 1.0 and 2.0 mole ratios. The field data for this study relating applied chlorine dose minus total chlorine

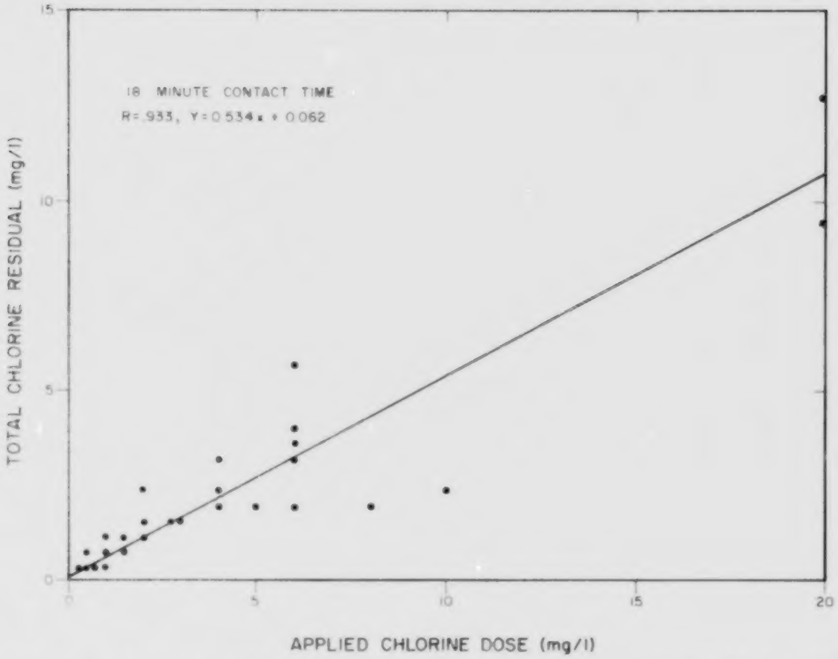


Figure 51. Observed total chlorine residual remaining after 18 minutes contact time only versus chlorine dosage using filtered lagoon effluent.

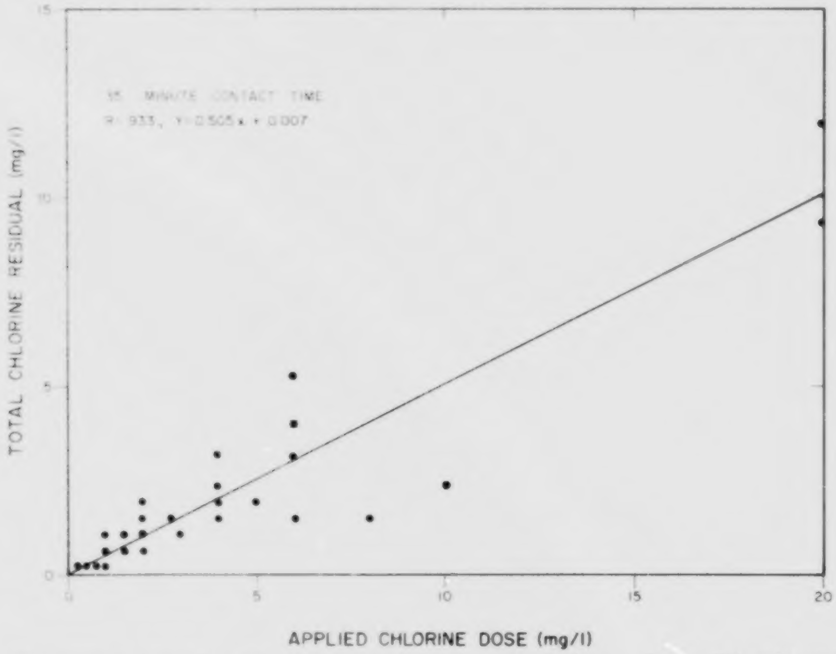


Figure 52. Observed total chlorine residual remaining after 35 minutes contact time only versus chlorine dosage using filtered lagoon effluent.

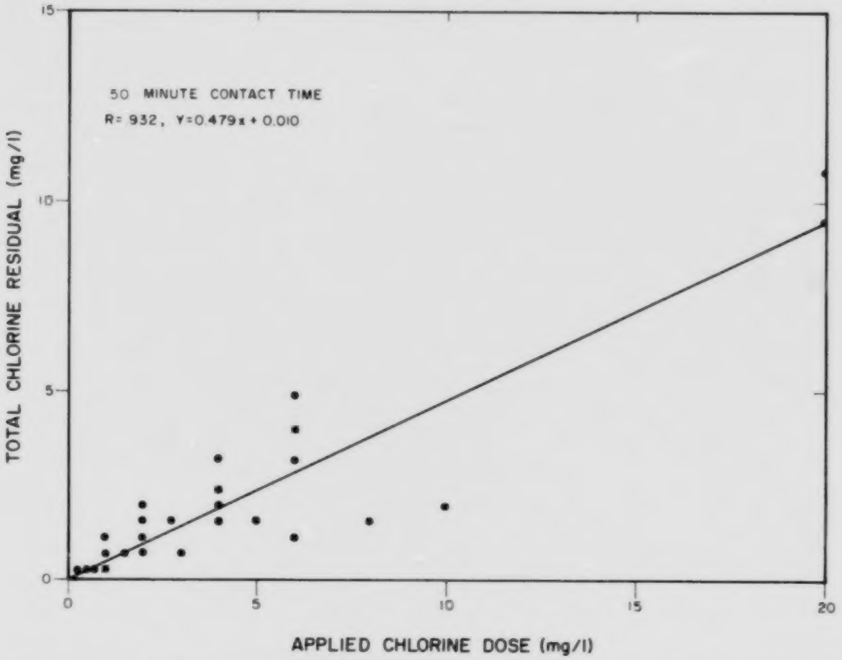


Figure 53. Observed total chlorine residual remaining after 50 minutes contact time only versus chlorine dosage using filtered lagoon effluent.

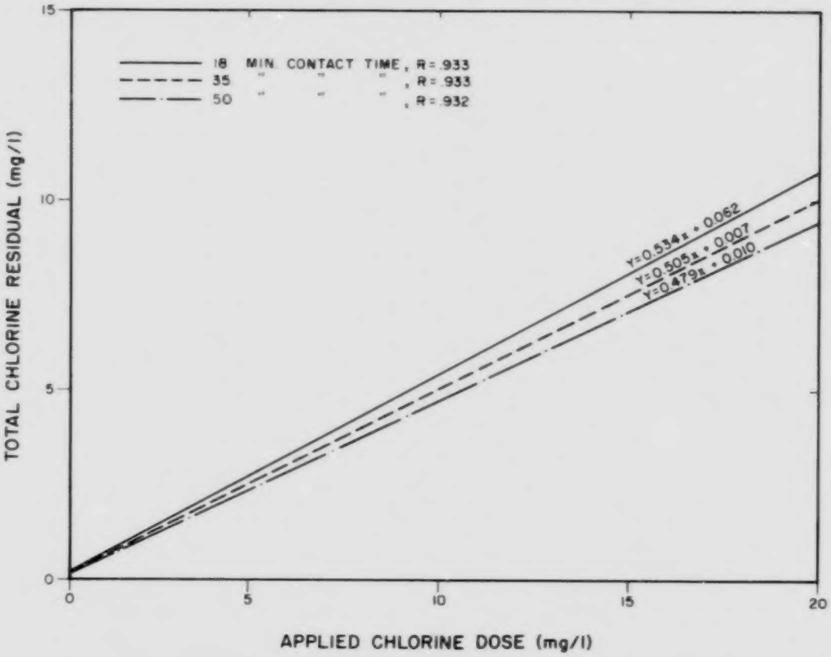


Figure 54. Summary of total chlorine residual remaining after various contact times versus chlorine dosage using filtered lagoon effluent.

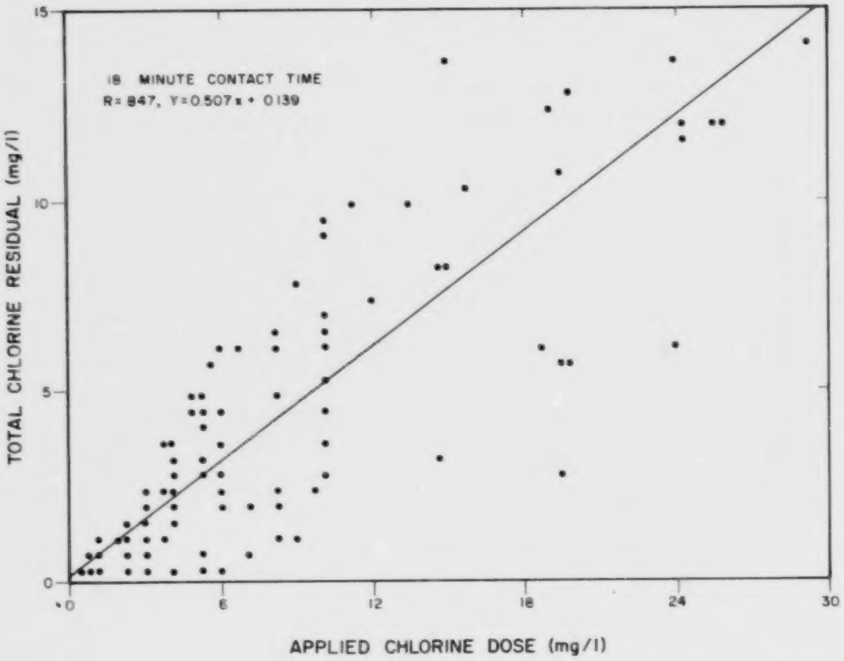


Figure 55. Observed total chlorine residual remaining after 18 minutes contact time versus chlorine dosage using unfiltered lagoon effluent.

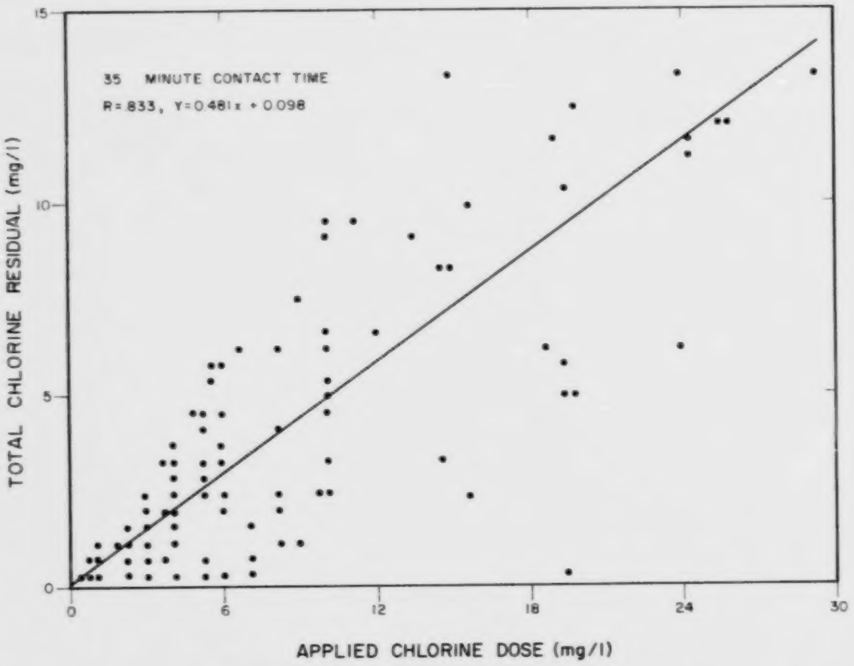


Figure 56. Observed total chlorine residual remaining after 35 minutes contact time versus chlorine dosage using unfiltered lagoon effluent.

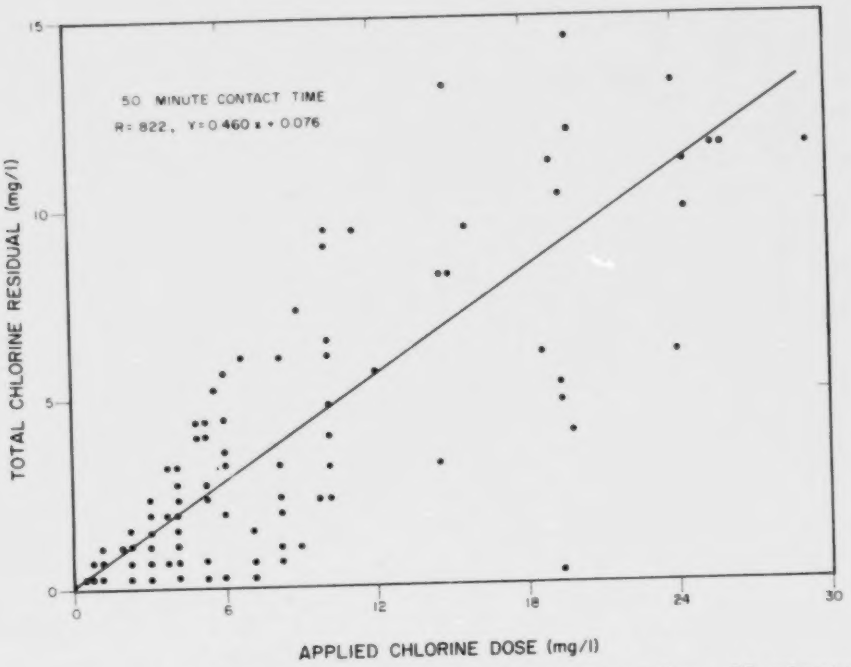


Figure 57. Observed total chlorine residual remaining after 50 minutes contact time versus chlorine dosage using unfiltered lagoon effluent.

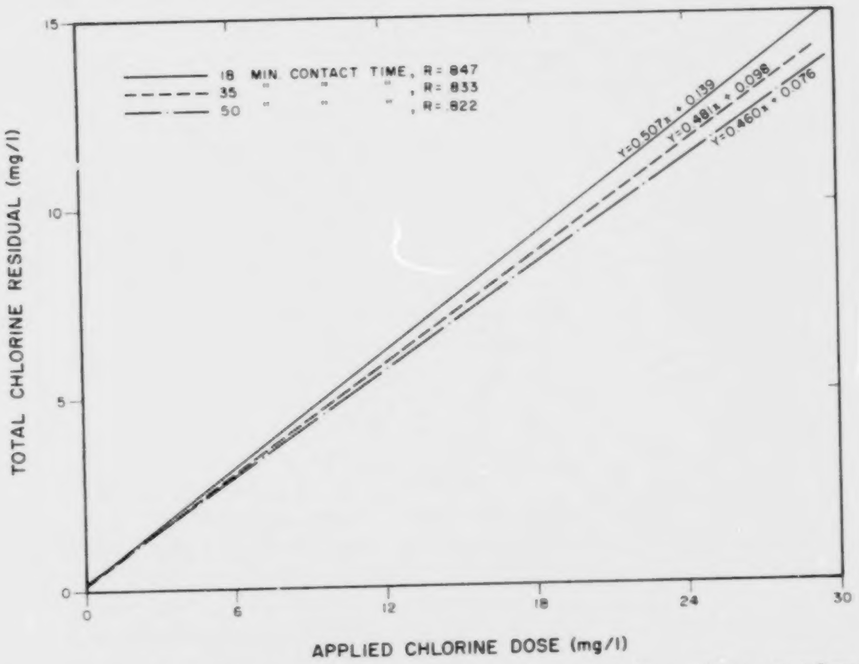


Figure 58. Summary of total chlorine residual remaining after various contact times versus chlorine dosage using unfiltered lagoon effluent.

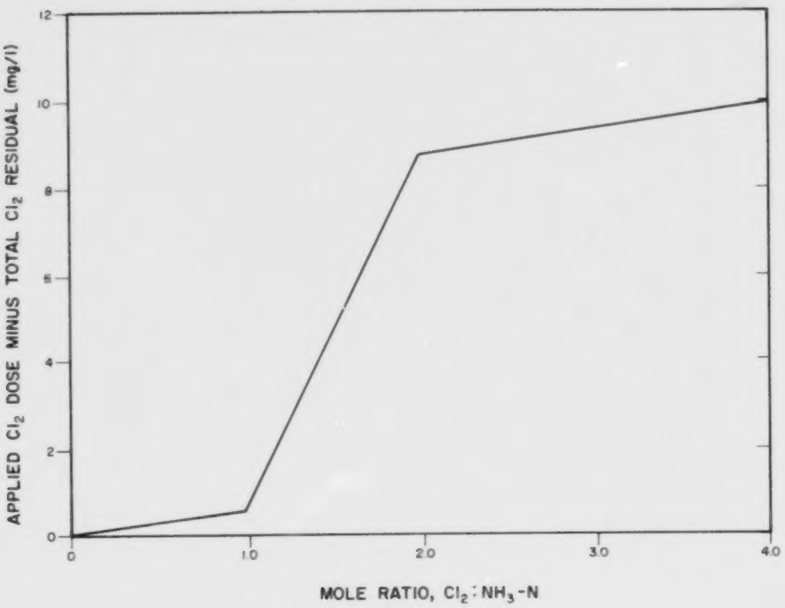


Figure 59. An adaptation of the chlorine breakpoint curve with $Cl_2:NH_3$-N mole ratios.

residual to $Cl_2:NH_3$-N ratios for filtered and unfiltered lagoon effluent are illustrated in Figures 60 and 61. The data in both Figures 60 and 61 are widely dispersed and no resemblance to Figure 59 can be observed. No consistent change in chlorine demand with respect to $Cl_2:NH_3$-N mole ratios is indicated by either of these two figures. Regression analysis of Figure 61 (unfiltered lagoon effluent) does indicate an overall increase in slope over the entire mole ratio range. However, the confidence intervals are greater than 50 percent and the correlation does not approach the 5 percent level of significance. Correlation coefficients fall in the range of 0.08-0.31 and are also greater than the 50 percent level of statistical significance. Regression analysis of the filtered lagoon effluent data do not show any consistent increases in regression line slopes (i.e. negative slopes are obtained along with positive slopes when performing linear regression analysis on the 0.0-1.0, 1.0-2.0, 2.0-4.0 $Cl_2:NH_3$-N mole ratio ranges). In summary, results obtained from Figures 60 and 61 do not show the expected results predicted by Figure 59.

Lagoon effluents contain various concentrations of inorganic and organic nitrogenous compounds. The breakpoint curve (Figure 1) indicates what occurs in relatively pure laboratory water containing ammonia and chlorine. Influences of the other nitrogenous compounds as well as other organic and inorganic materials may hinder the development of a similar breakpoint curve and thus produce the results observed in Figures 60 and 61. These results indicate that no conclusive effect on chlorine demand by ammonia can be determined without additional data (i.e. nitrites, nitrates, total organic nitrogen, etc.).

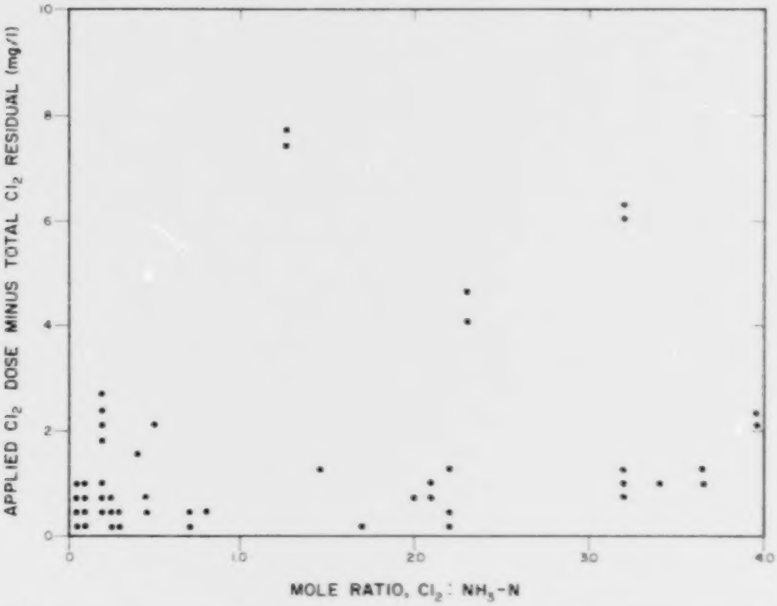


Figure 60. Chlorine demand with respect to Cl_2:NH_3-N mole ratios for filtered lagoon effluent.

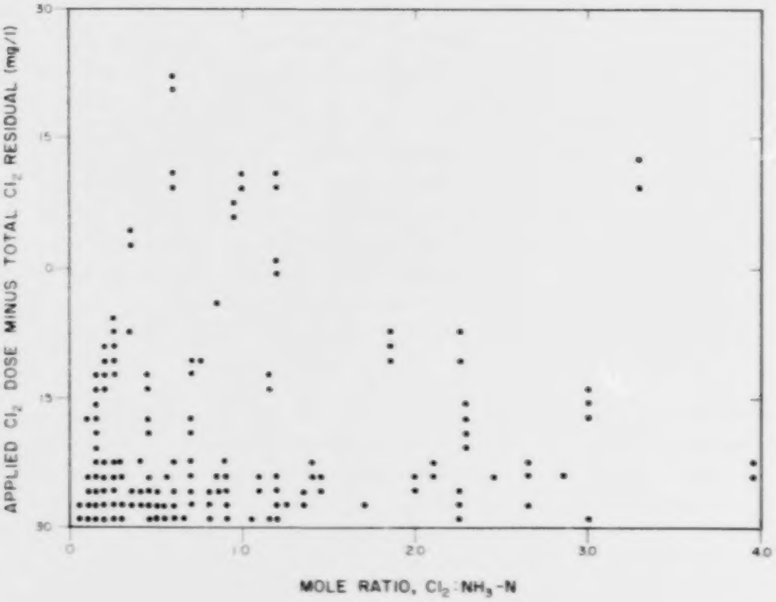


Figure 61. Chlorine demand with respect to Cl_2:NH_3-N mole ratios for unfiltered lagoon effluent.

Effects of Temperature on Chlorine Residual--

General--The effect of temperature on the level of chlorine residual produced from chlorination practices is of interest due to the reports that lower temperature will create the need for greater chlorine dosage to achieve the same level of coliform reduction (Reid and Carlson, 1974).

Unfiltered lagoon effluent--The unfiltered lagoon effluent field data suggest agreement with the above concept. Figures 62-65 indicate the effects of temperature at 0°-5°, 5°-10°, 10°-15°, and greater than 15°C ranges on the relationship between chlorine dosage and total chlorine residual. The overall effect of temperature is summarized in Figure 66, which indicates that total chlorine residuals will increase with increasing temperatures. The 5°-10°C and the 10°-15°C regression lines in Figure 66 were not significantly different in slope. This indicates that the relationship of total chlorine residual to applied chlorine dose over the temperature range of 5°-15°C is essentially the same. These temperature ranges were selected to compare the results of this study to earlier reported findings (Butterfield, 1943; Reid and Carlson, 1974). Analysis of Figure 66 indicates that approximately 83 percent more applied chlorine is required to obtain the same concentration of total chlorine residual at the 0°-5°C temperature range over the greater than 15°C temperature range for the unfiltered lagoon effluent.

Filtered lagoon effluent--The indication that chlorine demand will increase with a decrease in temperature was not observed with filtered lagoon effluent data. Figures 67-70 present the data for varying temperature ranges plotted to illustrate their effects on chlorine demand. Figure 71 is a summary of Figures 67-70. Figure 71 does not indicate the trend noted with unfiltered lagoon effluent. This could possibly be attributed to the fewer number of data available; or perhaps this pattern does not exist with filtered lagoon effluent regardless of what reported literature suggests. With a higher quality effluent (reduced solids, ammonia, BOD_5, etc.) the temperature may not have any definite impact on chlorine residual formation.

MODEL DEVELOPMENT

General

A basic model to be used in optimizing the chlorination of waste stabilization lagoon effluent was developed with the objective of constructing a practical design model for application under typical lagoon conditions. This required a determination of the significant relationships pertaining to the chlorination process. Information obtained from the literature was used to estimate the parameters and relationships likely to be most important. Upon examination of field and laboratory data, the parameters observed to be least important were eliminated from consideration. The most acceptable approach in representing chemical and biological interactions was considered to be the application of chemical reaction kinetics. This approach was used wherever possible and practical. Optional provisions were made to enhance model sophistication. These provisions, however, required significantly more computer time and, therefore, restricted the practical applicability of the model.

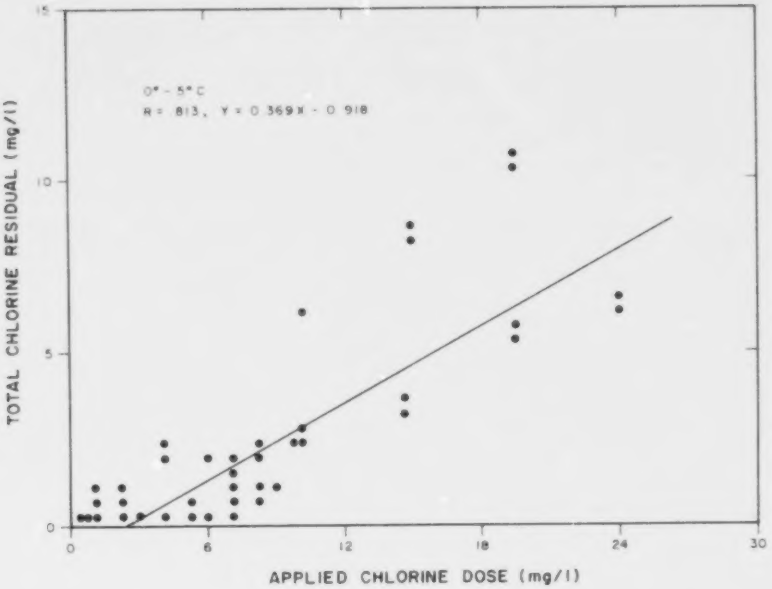


Figure 62. Total chlorine residual remaining at 0°-5°C versus chlorine dosage using unfiltered lagoon effluent (contact time = 50 min).

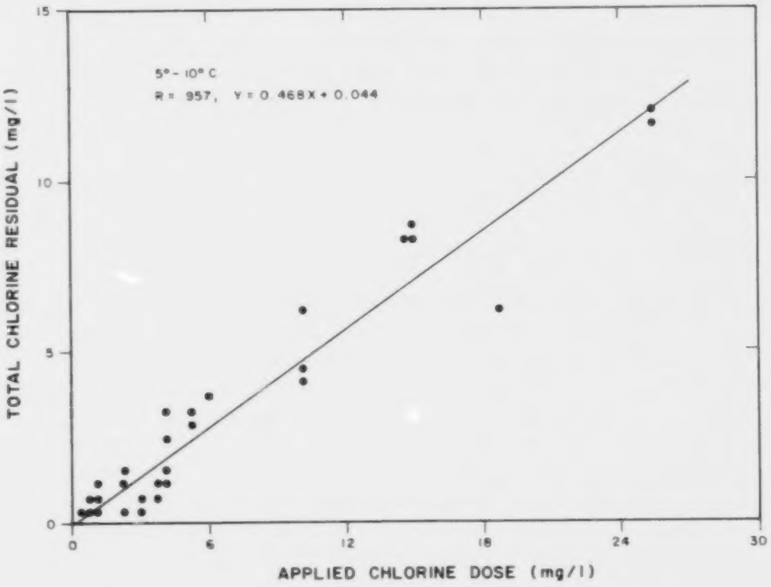


Figure 63. Total chlorine residual remaining at 5°-10°C versus chlorine dosage using unfiltered lagoon effluent (contact time = 50 min).

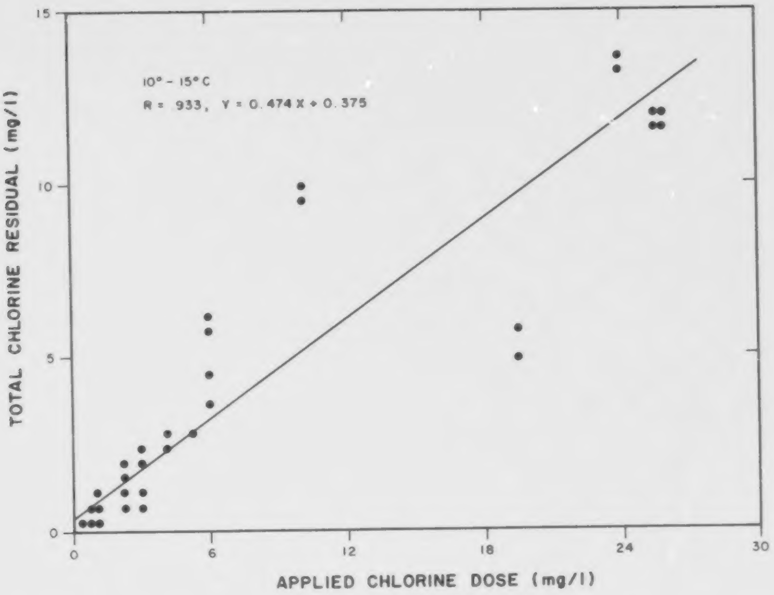


Figure 64. Total chlorine residual remaining at 10°-15°C versus chlorine dosage using unfiltered lagoon effluent (contact time = 50 min).

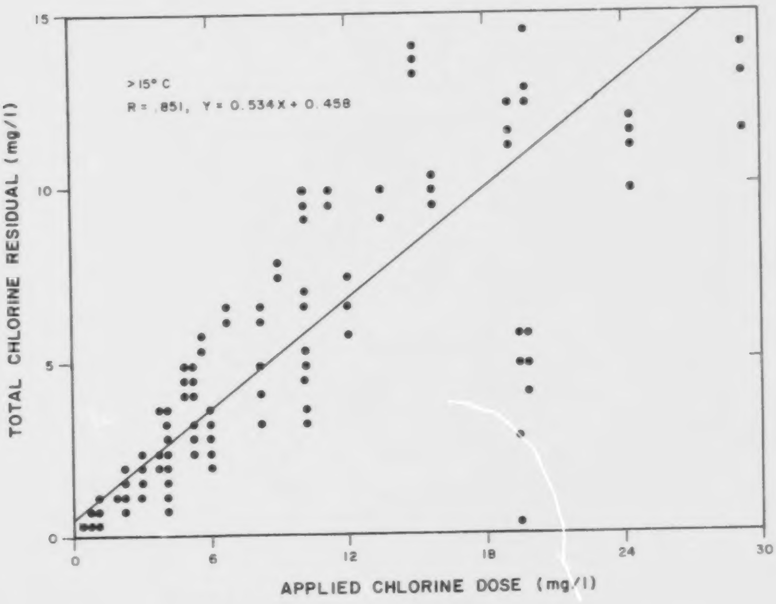


Figure 65. Total chlorine residual remaining at >15°C versus chlorine dosage using unfiltered lagoon effluent (contact time = 50 min).

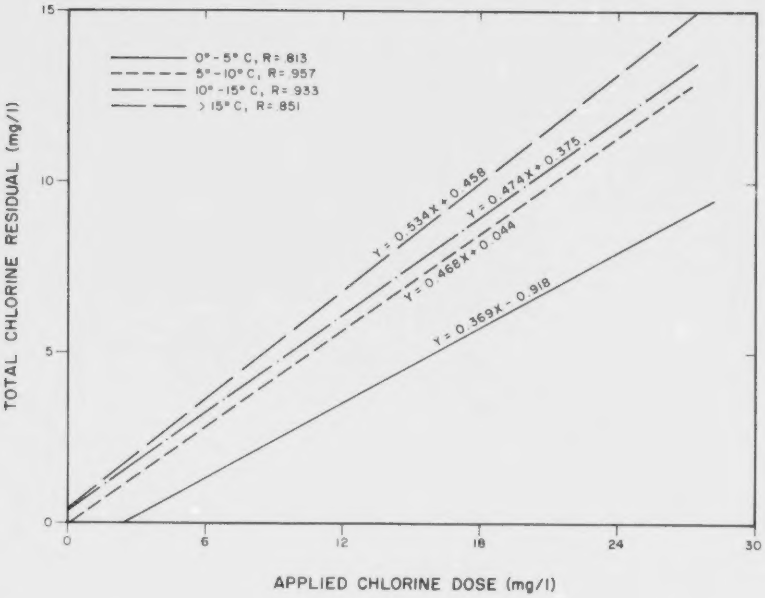


Figure 66. Summary of temperature effects on the relationship between total chlorine residual and applied chlorine dosage using unfiltered lagoon effluent (contact time = 50 min).

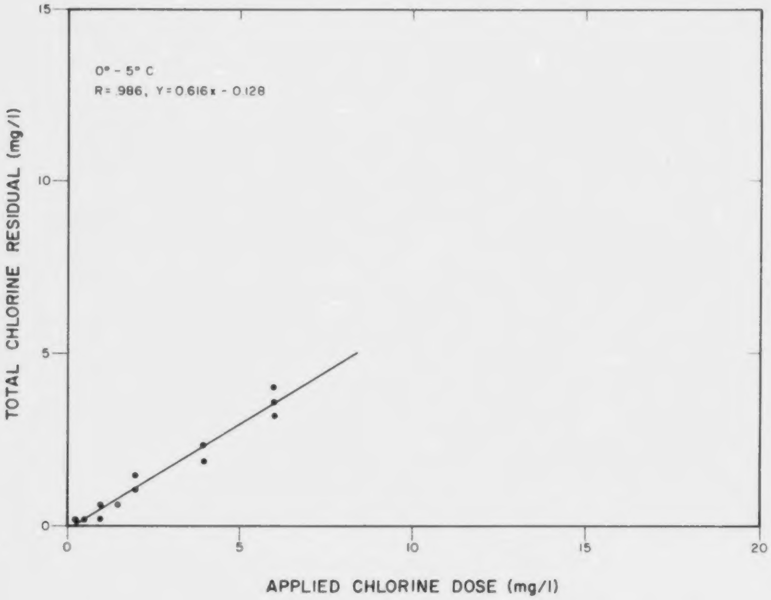


Figure 67. Total chlorine residual remaining at 0^{o}-5^{o}C versus chlorine dosage using filtered lagoon effluent (contact time = 50 min).

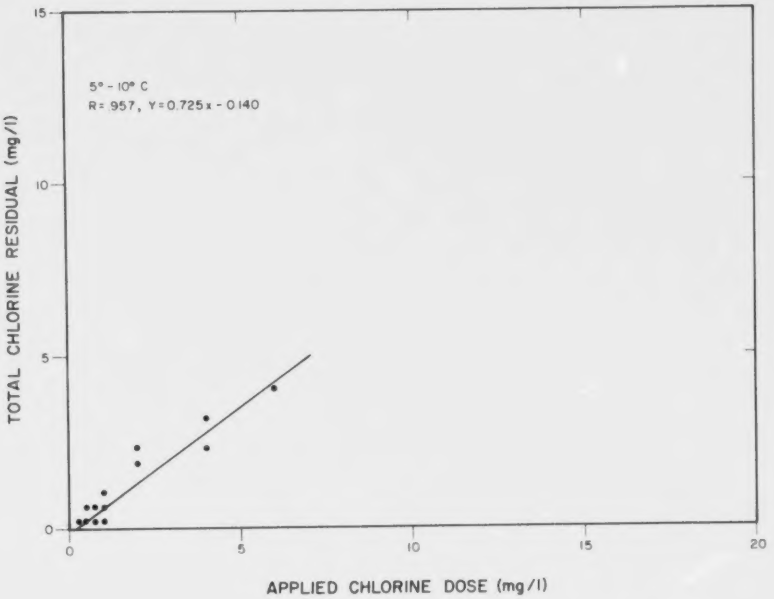


Figure 68. Total chlorine residual remaining at 5°-10°C versus chlorine dosage using filtered lagoon effluent (contact time = 50 min).

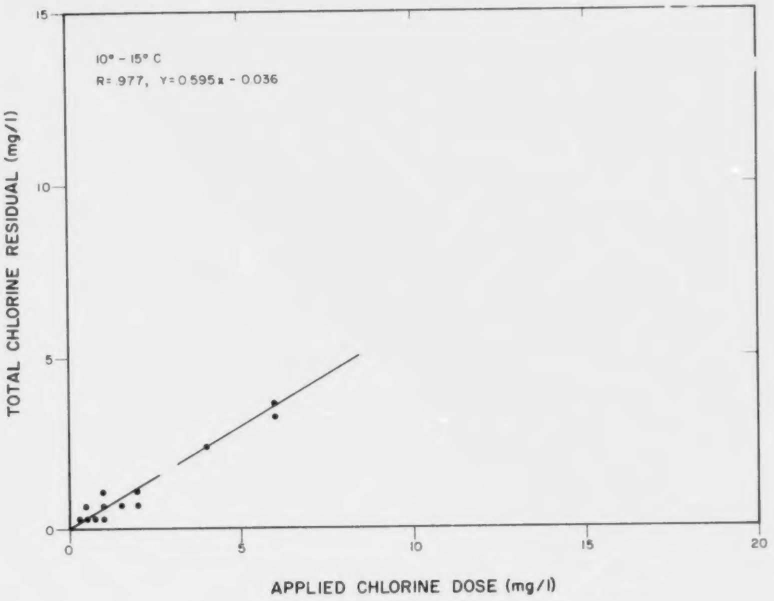


Figure 69. Total chlorine residual remaining at 10°-15°C versus chlorine dosage using filtered lagoon effluent (contact time = 50 min).

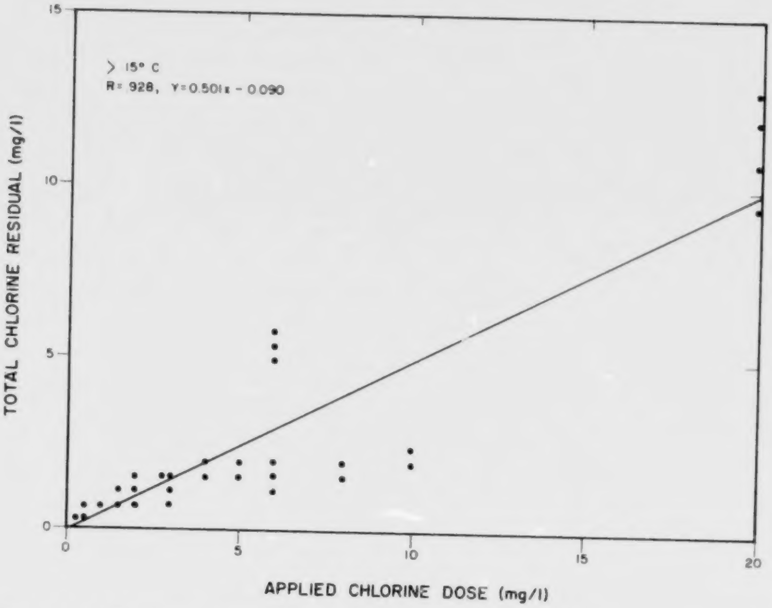


Figure 70. Total chlorine residual remaining at >15°C versus chlorine dosage using filtered lagoon effluent (contact time = 50 min).

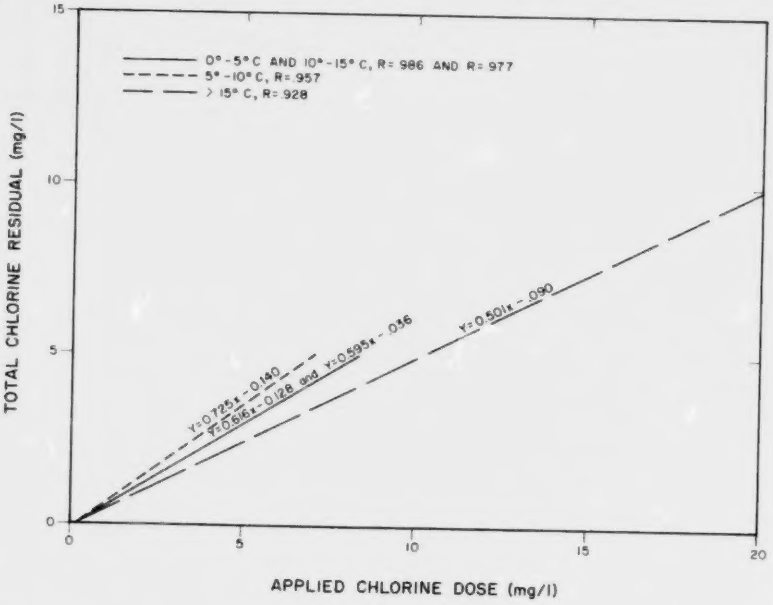


Figure 71. Summary of temperature effects on the relationship between total chlorine residual and applied chlorine dosage using filtered lagoon effluent (contact time = 50 min).

Inspection of field data provided observations which allowed for model simplification. One of these observations involved the practice of breakpoint chlorination. The breakpoint, and thus, the production of free chlorine residual, was reached for less than 6 percent of the total data after a contact time of 18 minutes. Free chlorine residual was observed only when chlorine dosages higher than necessary to achieve adequate disinfection were applied concurrently with low NH_3-N concentrations. In all cases involving breakpoint chlorination, MPN fecal coliform counts were reduced to less than 2/100 ml in less than 18 minutes. All but two MPN total coliform counts were also reduced to less than 2/100 ml in the same contact time. From this observation, it can be concluded that it should seldom, if ever, be necessary to use breakpoint chlorination to achieve satisfactory disinfection for lagoon effluents. Since the mechanisms and kinetics involved in breakpoint chlorination are only rarely applied, they can be eliminated or greatly simplified in the model. This is particularly welcome since, at present, little is understood about the breakpoint chemistry in wastewater containing high amounts of organic nitrogen.

For those times when free chlorine residual did appear, the NH_3-N concentrations in the unchlorinated lagoon effluent were generally found to be less than 1.0 mg/l. Usually, conditions of low ammonia concentrations resulted from algae blooms or from filtering effluent through intermittent sand filters. The biological reactions which occur with the intermittent sand filter substantially reduce lagoon effluent ammonia concentrations. For this particular lagoon system, algae blooms were observed in early September, 1975, early May, 1976, and late June, 1976. Fortunately, bacterial concentrations were also reduced as a result of filtering and algae blooms. Thus, less chlorine dose was required to achieve disinfection. Under these conditions, satisfactory bacterial removal should be achieved without resorting to breakpoint chlorination.

During six weeks in March and early April, 1976, it was observed that as much as six to seven times more chlorine was required to produce the same residual as observed during other times of the year. This was apparently a result of anaerobic conditions created by the lagoons freezing over during the winter months. Under conditions of very little dissolved oxygen, hydrogen sulfide (H_2S) levels as high as 1.8 mg/l were produced. H_2S reacts very rapidly with chlorine, reducing it to the innocuous chloride ion. Therefore, it became obvious that provisions in the model must be made to predict changes in sulfide concentrations and to determine the amount of chlorine consumed by H_2S.

One other field observation was important in formulating the model. Generally, the pH value for the untreated effluent remained between 8.0 and 9.0 during most of the year. Occasionally, the pH value dropped to as low as 7.5 or rose to as high as 9.5. The lagoon effluent was observed to possess excellent buffering capacity. The pH was shifted only under conditions of very high chlorine doses. These variations in pH could be considered to be quite important if free residual chlorination was being used. However, since most of the disinfection is accomplished with combined chlorine, the slight altering of the distribution of chloramines across this pH range is less critical in achieving satisfactory disinfection. In general, this pH range is typical of other lagoon systems; therefore, little attention need be given to the effects of pH on combined chlorine disinfection of lagoon effluent. To provide for conditions where pH may be important, however, a model option is included for determining the distribution of chlorine species as a function of pH.

With these field observations and with information derived from literature and laboratory experiments previously discussed, a general structure for the mathematical model was developed. The basic model was developed based upon the following general assumptions and considerations.

1. The chlorine demand exerted by sulfide occurs so rapidly that it is considered to be instantaneous.

2. The hydrolysis of chlorine gas in aqueous solution is instantaneous and complete.

3. Because of the lack of appropriate field data and since extremely low coliform counts were in the presence of any free residual chlorine, no distinction was made between the disinfection properties of hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). These two components were treated together as free chlorine.

4. Breakpoint chlorination was considered to have little or no practical value in lagoon disinfection. Therefore, the representation of breakpoint reactions was reduced to a simplified steady state approach.

5. It was assumed that in all cases, satisfactory disinfection can be achieved with combined chlorine residual.

6. Because reactions between chlorine and ammonia occur so much more rapidly than bacterial disinfection, chloramine formation is considered to be instantaneous. No distinction is made between species of chloramines and all are treated as combined chlorine.

7. Chemical reaction kinetics for batch and plug flow reactors as described by Levenspeil (1962) are used to describe the dynamic portion of the model.

8. The effects of chlorination on pH were neglected because of the buffering capacity of the particular lagoon effluents studied.

9. Temperature dependence was assumed for the rates of disinfection and exertion of chlorine demand. Changes in rates of chemical reactions are described using the Arrhenius equation.

10. The rate at which chlorine demand is exerted is considered to be a function of the concentration of suspended and soluble, organic and inorganic oxidizable materials, as well as the concentration of chlorine residual. Total chemical oxygen demand (TCOD), therefore, is used in describing chlorine demand.

11. Soluble chemical oxygen demand (SCOD) and suspended solids (SS) are two water quality parameters which have the potential of being altered by the chlorination process and, therefore, are included in the model.

The basic model, hereafter known as CHLOR-I, is restricted in application to chlorine contact chambers approaching plug flow hydraulic conditions. Dispersion is not considered in this model. Alterations to enhance the sophistication of the basic model are discussed under the heading "Model options" and are incorporated in a second model referred to as CHLOR-II. Complete listings of the computer programs, along with descriptions of variables for CHLOR-I and CHLOR-II, are included in Appendix F and Appendix G, respectively. Detailed descriptions of the development of both models are contained in the following sections.

Sulfide

According to Laubusch (1962), Karchmer (1970), and Chen (1974), the theoretical weight ratio of chlorine consumed to sulfide oxidized is 8.5:1. However, as these authors have indicated, it is possible to produce a chlorine residual with dosages well below this ratio. This indicates that sulfides are not necessarily completely oxidized by chlorine. Under conditions of complete oxidation, the following reaction takes place.

$$4HOCl + H_2S \rightarrow H_2SO_4 + 4HCl \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (34)$$

This reaction is favored at pH 9. For lower pH values a smaller chlorine dose is required to remove sulfide. At pH 5, the following reaction is favored.

$$HOCl + H_2S \rightarrow HCl + H_2O + S\downarrow \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (35)$$

Further oxidation by chlorine is slow once elemental sulfur has been formed. The chlorine dose required to remove sulfide is reduced by 75 percent in dropping from pH 9 to pH 5. Since the pH of the lagoon effluent varied between 7.5-8.0 during the period for which sulfide was produced, it was anticipated that the ratio of chlorine to sulfide would be somewhat less than that required for complete oxidation.

Nickless (1968) has pointed out that the reactions between chlorine and sulfide are extremely rapid and often quite violent. Although actual kinetic data are limited, it is assumed from literature previously referenced and field observation that the reactions are rapid enough to be considered instantaneous. Therefore, steady state assumptions are used to determine the amounts of chlorine and sulfide consumed as a result of chlorination.

One approach used by Chen (1972) to determine the amount of chlorine consumed per mole of sulfide reacted is described by the following empirical equation.

$$R = at^b \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (36)$$

in which

R = ratio of chlorine to sulfide reacted

t = reaction time in minutes

a = extent of reaction in one minute

b = rate of change in experimental ratio with time

It is important to point out that not all of the sulfide produced in an anaerobic system is in the form of H_2S. Studies performed by Gloyna and Espino (1969) on sulfide production in waste stabilization ponds indicates that at pH 7 only about 50 percent of the total sulfide produced is in the form of H_2S. Other sulfide forms can be expected to react differently with chlorine. This further complicates the determination of the amount of chlorine consumed by sulfide.

From evaluations of sulfide removal in sewage collection systems, Shepherd and Hobbs (1973) found that when 5 mg/1 of chlorine was added to wastewater containing 2.4 mg/1 sulfide, the sulfide concentration was reduced to 1.5 mg/1 after 40 minutes. For longer periods, regeneration of sulfide was observed. In the present study laboratory experiments indicated that 2.1 to 8.4 pounds of chlorine were required to remove one pound of H_2S. This compares with field data from the present study which indicates that 3 to 7 pounds of chlorine is required to remove 1 pound of H_2S.

Data from this study indicates that the ratio of chlorine consumed to sulfide oxidized is highly variable. The mean of all data gives a $Cl_2:S^=$ mole ratio of 2.54:1. Because of the high variability of the data, the median value was also selected to be used as an initial estimate of the moles of chlorine consumed per mole of sulfide. This value was determined to be 3.6:1, after eliminating several questionable data points. Both ratios fall within the range of theoretical mole ratios of 1:1 to 4:1. In applying the two ratios, it was found that the ratio 3.6:1 was more satisfactory when used in conjunction with the completed model.

When sulfide did appear in the lagoon effluent, the concentrations were generally between 1.0-1.8 mg/1. For this range of sulfide, a linear regression was performed to determine the relationship between chlorine dose and chlorine residual. The results of this regression are presented in Figure 72. It is expected that this relationship is quite different for sulfide concentrations above 1.8 mg/1 and below 1.0 mg/1. The results do indicate that once the chlorine demand exerted by sulfide is satisfied, sulfide plays no further role in affecting the chlorine dose to residual relationship.

It was observed from field data that after the application of chlorine, sulfides were reduced but not completely eliminated. The accuracy of the laboratory method used to evaluate sulfide may have contributed to this phenomenon. However, preliminary evaluations of the method indicated that it was accurate at levels above 0.1 mg/1 sulfide. Another explanation for the remaining sulfide may be that some sulfide was regenerated, as observed by Shepherd and Hobbs (1973). Also, some of the measured sulfide may have been associated with organic sulfide complexes, which were less readily oxidized by chlorine.

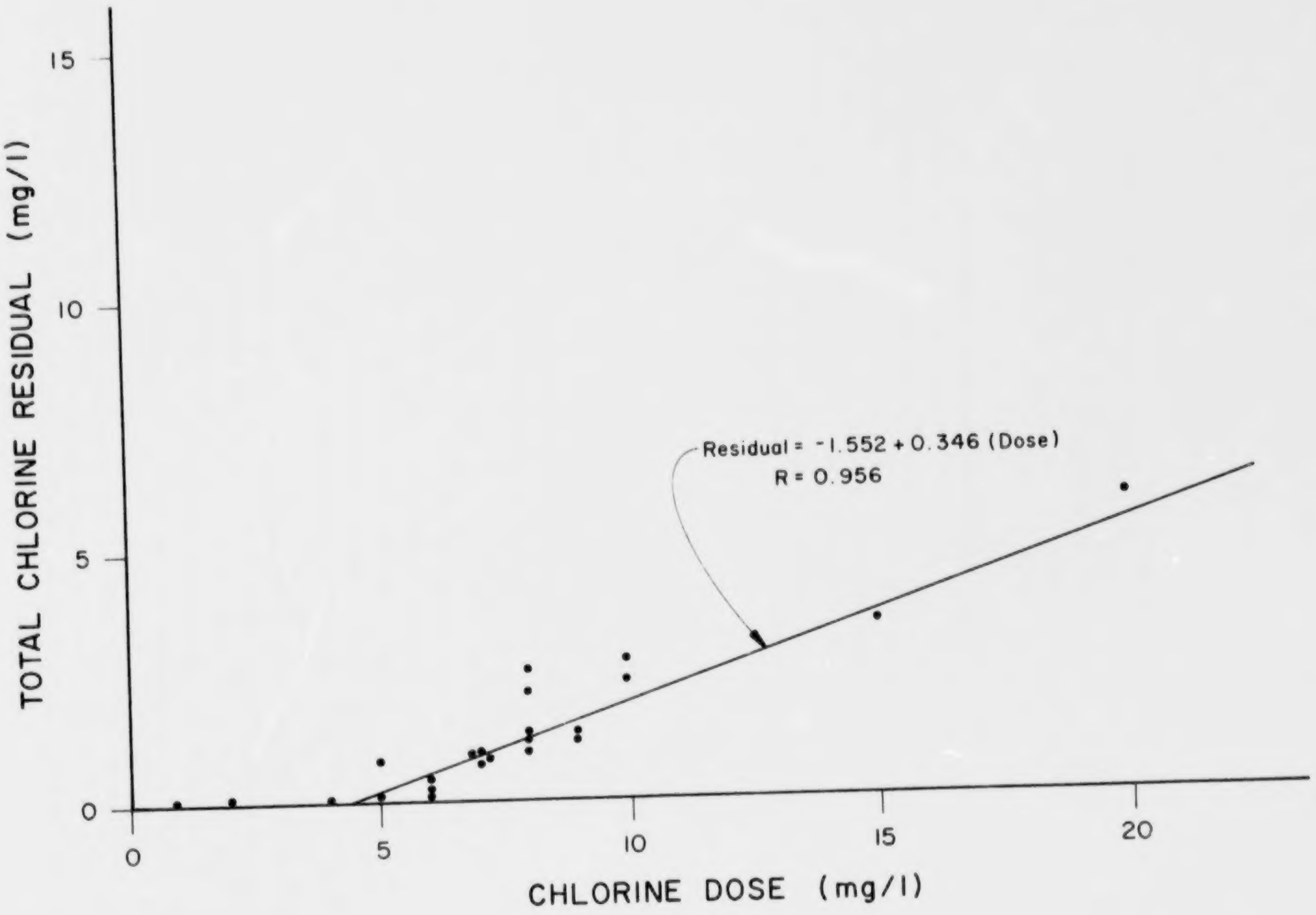


Figure 72. Chlorine residual vs. dose for initial sulfide concentrations of 1.0 - 1.8 mg/1.

The reduction, but incomplete elimination, of sulfide was considered to follow an exponential decay with increasing chlorine doses. Therefore, the following equation was assumed for predicting the amount of sulfide oxidized by chlorine.

$$S = S_L + (S_o - S_L)\, e^{K(Cl_2)} \quad . . . . \quad (37)$$

in which

S = mg/l sulfide remaining after a specified chlorine dose

S_o = mg/l initial sulfide concentration

S_L = lower limit of sulfide detection (0.1 mg/l in this case)

K = empirical constant

Cl_2 = mg/l chlorine dose

A regression analysis was performed on the field data to determine the value of K. This was found to be equal to -0.141, with a resulting correlation coefficient, R, of 0.674. This is significant at the 95 percent confidence level. An illustration of how predicted values compare with observed data for an initial sulfide concentration of 1.2 mg/l is presented in Figure 73. Upon application in CHLOR-I, the amount of sulfide consumed, as a function of chlorine dose, is calculated using Equation 37. The amount of chlorine required to oxidize the consumed sulfide is then determined from the $Cl_2:S^=$ ratio developed from field data.

Breakpoint Chlorination Approximation

As previously discussed, free chlorine residual was observed in less than 6 percent of the field data. Since breakpoint chlorination was found to be of limited practical value in application to wastewater, it was assumed that a steady state approximation of breakpoint kinetics was sufficient, in most cases, to describe the oxidation of chloramines and the appearance of free chlorine. Kinetically, the formation of chloramines is extremely rapid, particularly in comparison with the rate of disinfection. Therefore, steady state assumptions are also used in CHLOR-I to describe the reactions between chlorine and NH_3-N and organic nitrogen. This is a reasonable assumption since, as Jolley (1973) has pointed out, the reaction between HOCl and NH_3-N to form monochloramine is 99 percent complete within one minute. Reaction rates for the formation of other chloramines are also very rapid.

Although it has been well documented by White (1972) that the breakpoint is highly variable in wastewater, the ideal breakpoint curve, with modifications to represent reactions between chlorine and organic nitrogen, is used to approximate chloramine formation and oxidation. To examine the merit of this approach, a breakpoint chlorination curve for secondary lagoon effluent from the Logan Lagoon System was constructed during December, 1975. The results are shown in Figure 74. These results should not be interpreted as being typically representative for lagoon effluent. However, they do suggest that there is some basis for using the ideal breakpoint curve as a starting point to represent steady state assumptions previously described.

Major alterations to the shape of the breakpoint curve may be expected to result, at least in part, from reactions between chlorine and organic nitrogen.

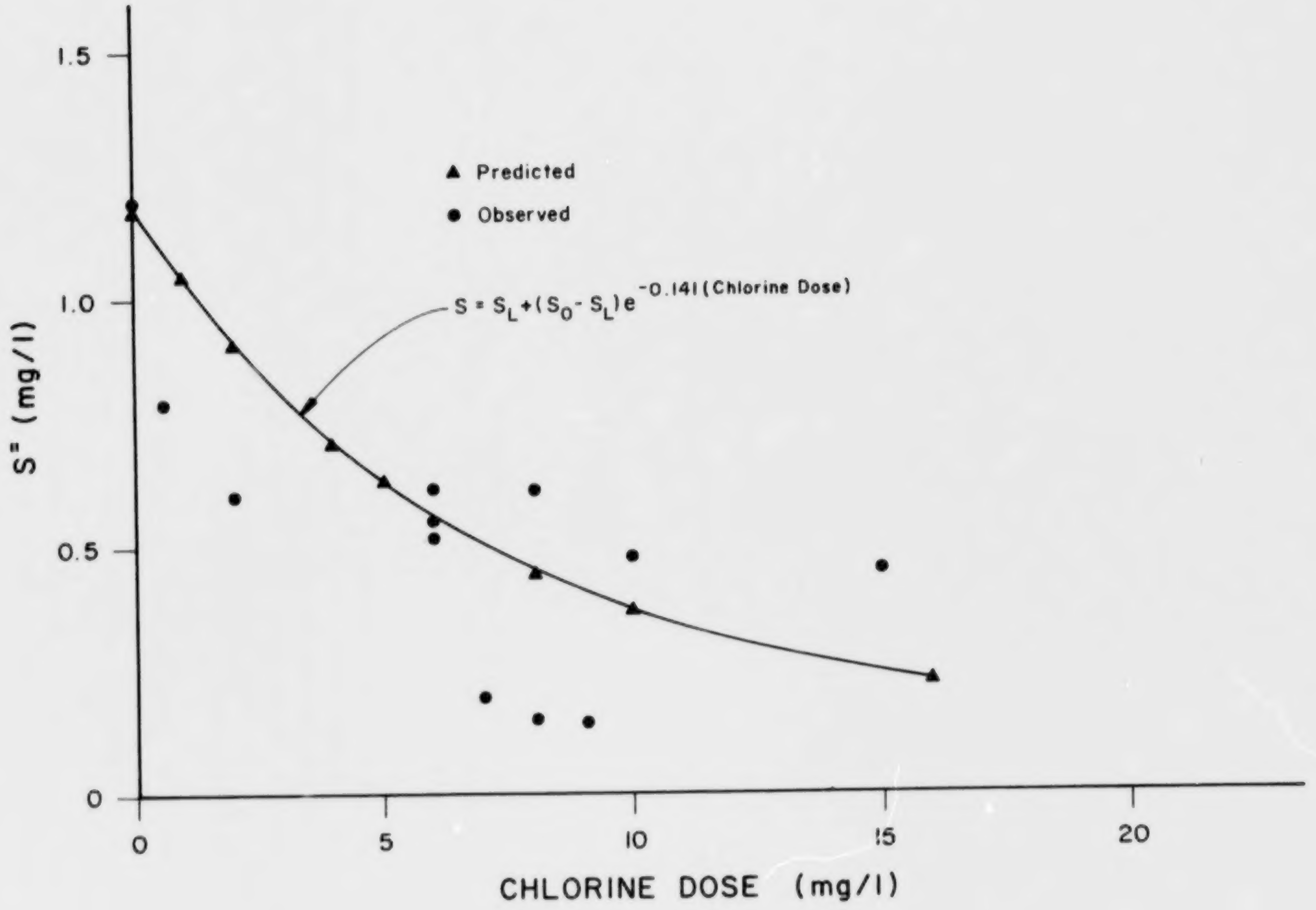


Figure 73. Sulfide vs. chlorine dose for initial sulfide = 1.2 mg/l.

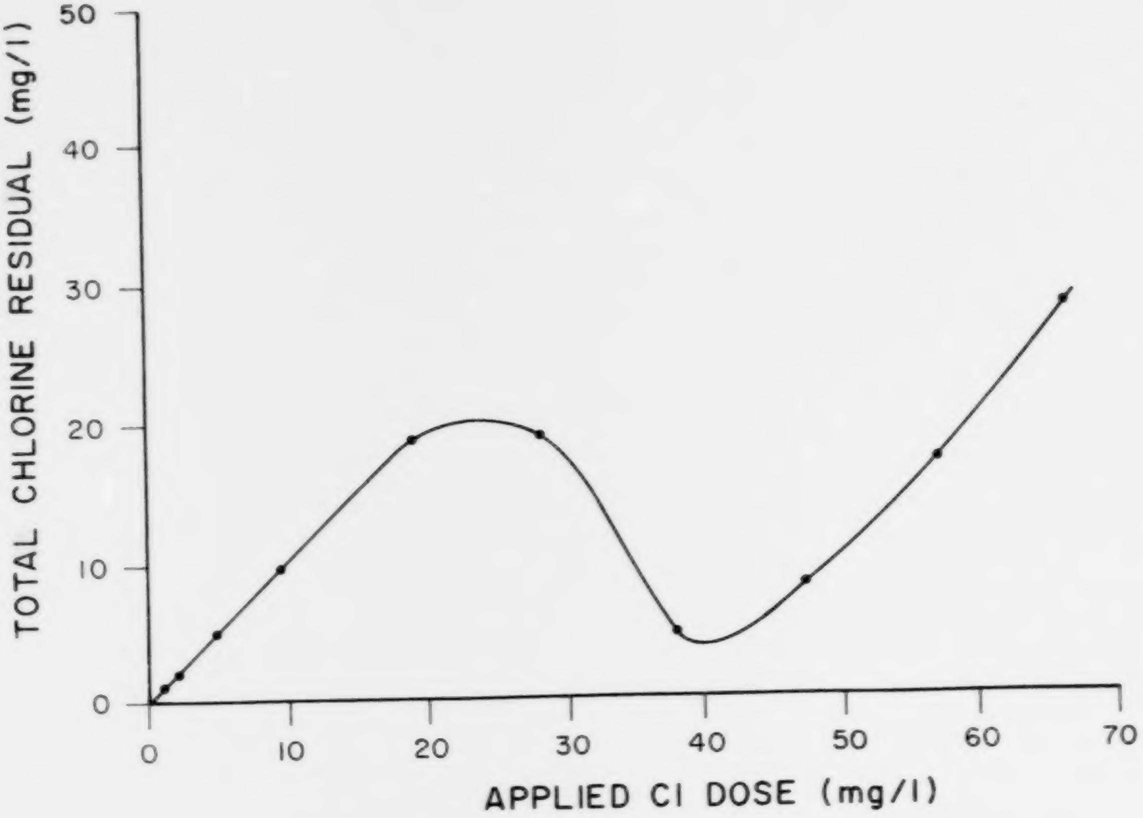


Figure 74. Breakpoint chlorination curve for secondary lagoon effluent sampled on December 15, 1975. Initial NH_3-N ≈ 5 mg/l. Contact time = 30 minutes.

Laubusch (1962) and Jolley (1973) have indicated that chlorine reacts with many organics. These reactions may include chlor-addition and substitution and even complete oxidation of organics. The rates of these reactions are also rapid enough for steady state assumptions to apply. As Jolley (1973) has pointed out, the formation of some organic chloramines is even faster than the formation of inorganic chloramines.

Data previously presented point out that the total kjeldahl nitrogen (TKN) content of lagoon effluent may be two, three, or more times greater than NH_3-N. It is not known if chlorine would react with all of the total nitrogen if a high enough dose were applied, or if all organic chloramines would be oxidized before free chlorine would appear. However, field data suggest that at least some of the proteins, amino acids, and other organic nitrogen compounds react with chlorine to produce compounds which are less readily oxidized by additional chlorine than are inorganic chloramines. Chlorine to ammonia molar ratios exceeding 1:1 with little apparent oxidation of chloramines give evidence of these types of reactions. This would explain in part why relatively large concentrations of combined chlorine, and even ammonia, remained after the appearance of the free chlorine. This observation suggests that a simple shifting of the ideal breakpoint curve to account for the formation of organic chloramines could be used to approximate the reactions between chlorine and total nitrogen.

In making an approximation of the breakpoint curve in CHLOR-I, a correction factor (CORNH3) is used to shift the ideal breakpoint curve. This factor is a function of the composition and quantity of nitrogenous material in addition to NH_3-N which could react with chlorine. Theoretically, the Cl_2:NH_3-N ratio is 1:1 for maximum chloramine formation in an ideal breakpoint curve. In application, the factor increases the Cl_2:NH_3-N molar ratio necessary to achieve maximum chloramine formation. Under ideal conditions, the Cl_2:NH_3-N molar ratio at the breakpoint is approximately 2:1. However, in application the breakpoint itself is shifted to the right by the same factor. The actual value of this ratio has been questioned by Wei and Morris (1974). They suggest that the ideal ratio of reduced chlorine to oxidized nitrogen is closer to 1.65:1 and that this value is independent of pH. Therefore, the 1.65:1 ratio is used in CHLOR-I to estimate breakpoint.

As the breakpoint is shifted horizontally, it is also shifted vertically to represent the complex N-chloro compounds which are not oxidized with the appearance of free chlorine. At this point, the chloramines formed from the reaction between chlorine and NH_3-N have been completely oxidized. This corresponds with a reduction of measured NH_3-N. As the Cl_2:NH_3-N ratio increases beyond breakpoint, the combined chlorine residual remains constant, subject to the exertion of chlorine demand, while free chlorine residual increases. An example of the shift in the shape of the breakpoint curve is illustrated in Figure 75 for a correction factor of 0.5.

Chemical Oxygen Demand

As previously discussed, the results from laboratory experiments indicate that there is little or no change in total chemical oxygen demand (TCOD) with increases in applied chlorine dose. However, it was also observed that under some conditions there was a tendency for chlorine to break down suspended organic solids into soluble organics as evidenced by increases in soluble chemical oxygen demand (SCOD). This condition was particularly noticeable when there were large initial concentrations of suspended chemical oxygen demand (TCOD minus SCOD) and high combined and free chlorine residuals, as shown in Figure 16.

In examining the field data, it was observed that there was very little change in SCOD with increasing chlorine doses for the filtered lagoon effluent. This is shown in Figure 28 and indicates that the removal of suspended chemical oxygen demand also removes the organics and inorganics which chlorine could oxidize to increase the SCOD. However, the same trend was also observed for unfiltered lagoon effluent as shown in Figure 29. This suggests that the type of chlorine residual, free or combined, may also have an impact on changes in SCOD. It is reasonable to assume that free chlorine would more readily oxidize

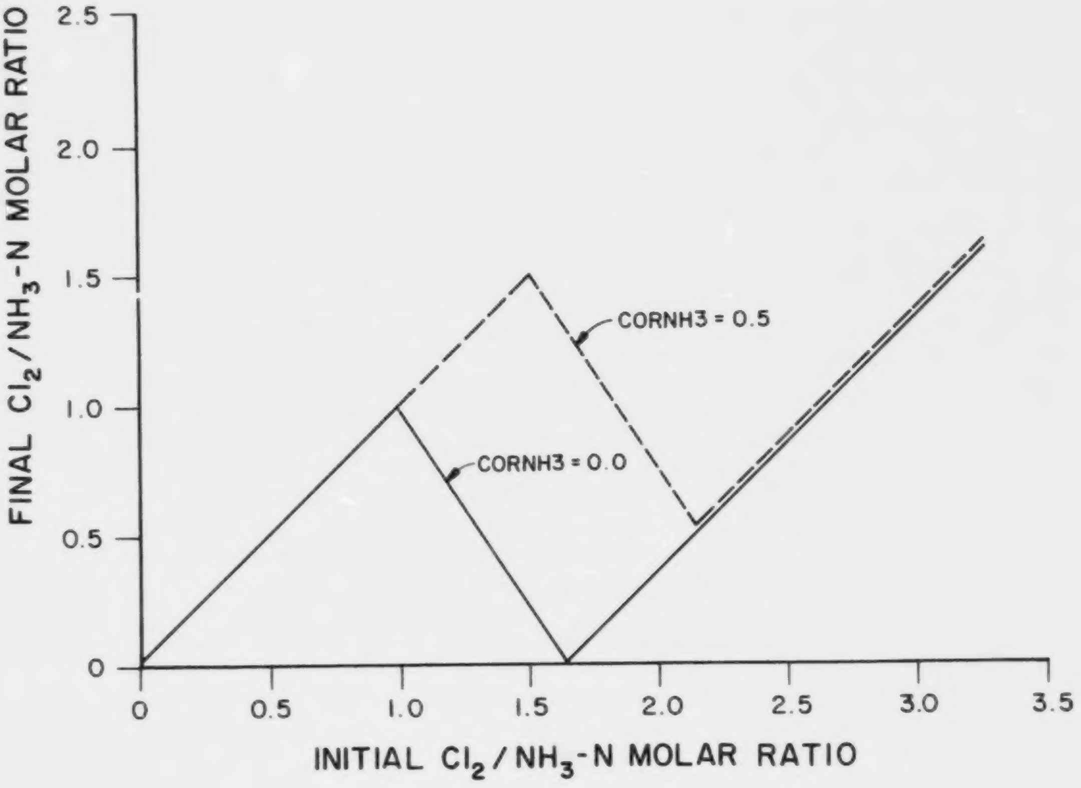


Figure 75. Shift in the breakpoint curve using a CORNH3 factor of 0.5.

chemical oxygen demanding particulates to increase the SCOD. Therefore, the changes in unfiltered effluent as a function of free chlorine residual were examined. The results, as shown in Figure 32, indicate that there is a correlation between increases in SCOD and free chlorine residual. The same trend was not observed, however, for free chlorine and filtered lagoon effluent. This was because of lower concentrations of suspended oxygen demanding solids and limited free chlorine data.

Using the information derived from laboratory and field observations, it has been hypothesized that increases in SCOD result from the reaction between free chlorine (FCl) and suspended chemical oxygen demand (TCOD minus SCOD). This can be expressed by the following equation:

$$\text{FCl} + (\text{TCOD} - \text{SCOD}) \rightarrow \Delta\text{SCOD} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (38)$$

If second order kinetics are assumed, the rate of increase in SCOD can be determined from the following rate equation:

$$\frac{D(\text{SCOD})}{dt} = \text{CCl}\ (\text{FCl})\ (\text{TCOD} - \text{SCOD}) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (39)$$

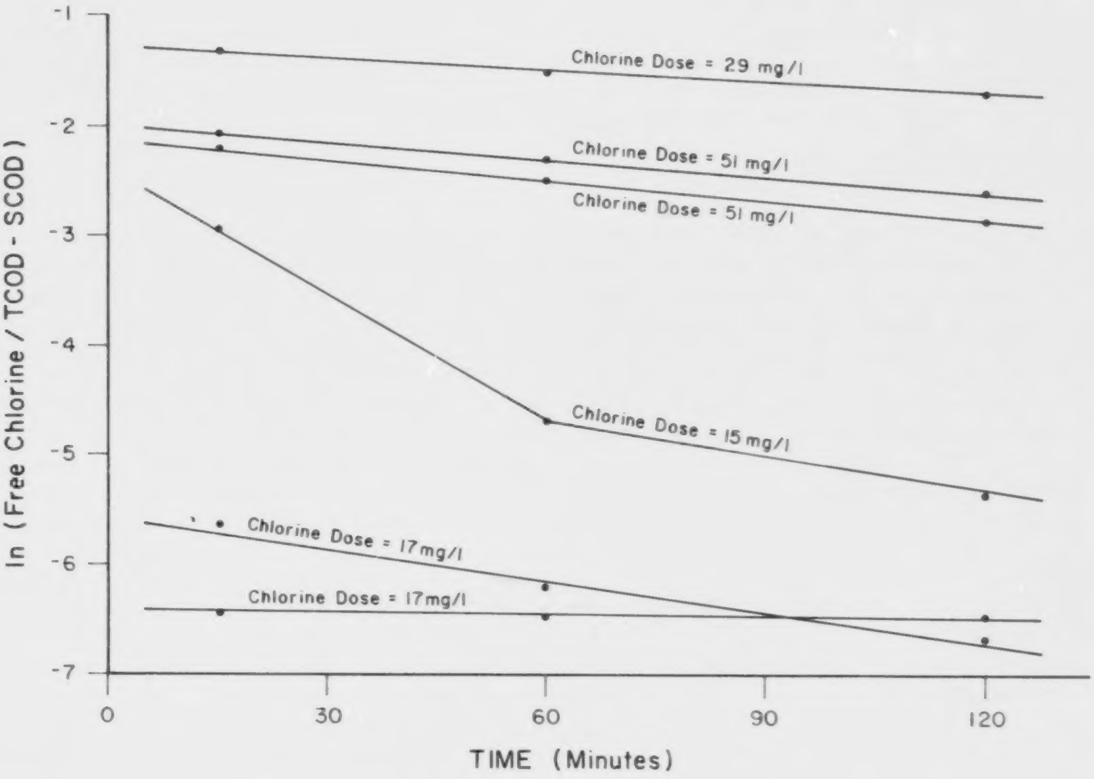


Figure 76. Determination of reaction order between free chlorine and suspended COD.

In this equation, CCl is a rate constant expressed in 1/mg-min.

To determine if second order kinetics are actually followed in this reaction, an approach described by Levenspeil (1962) was used. A plot of ln (FCl/(TCOD - SCOD)) versus time was constructed for several pieces of data, as shown in Figure 76. A straight line plot indicates second order kinetics. Since most of the lines are straight in Figure 76, it was concluded that the reaction is indeed second order.

Using second order kinetics and laboratory data, a regression analysis was performed to determine the value of CCl. Laboratory data were used in order to eliminate some of the variables associated with field data. The result of the regression is represented by the following equation.

$$\frac{d(\mathrm{SCOD})}{dt} = (7.24 \times 10^{-4})(\mathrm{FCl})(\mathrm{TCOD} - \mathrm{SCOD}) \quad . \ . \ . \ . \ . \ . \quad (40)$$

The rate of SCOD change is in units of mg/l-min. The correlation coefficient, R, obtained from this regression was 0.74. This value of R is significant at the 95 percent confidence level; therefore, the determined value of CCl is used in CHLOR-I to describe increases in SCOD.

Suspended Solids

Suspended solids (SS) concentrations were largely composed of volatile suspended solids (VSS), and the discussion of the effects of chlorine on SS also refers to the effects of chlorine on VSS. Laboratory data suggest that reductions in SS may result directly from chlorination. Evaluation of field data also shows reduction of solids between unchlorinated and chlorinated lagoon effluent. The changes in solids before and after chlorination for both filtered and unfiltered lagoon effluents are shown in Figures 30 and 31. From data previously presented, it is known that most of the reduction of SS in the field data is the result of settling. However, it is not known if chlorine assists in settling by acting as a flocculent aid. To reduce the effects of undefined variables, initially only laboratory data were used to determine the correlation between chlorine and suspended solids. Later, field data were also used to determine the values of rate constants. This was done by eliminating from consideration the time period during which most of the settling was observed to occur, and examining the remaining data. Although it is expected that free chlorine is more important in oxidizing SS, there was no confirming evidence, as there was in evaluating SCOD increases, to indicate that combined chlorine is not involved in the reduction of SS. Also, the ratio of free and combined chlorine which causes SS to settle during the chlorination process is not known. Therefore, it was initially assumed that both free chlorine (FCl) and combined chlorine (CCl) react with SS to cause reductions, either by oxidation or by flocculation.

If second order kinetics are assumed, the following equations may be used to describe the reaction between chlorine and SS:

$$\text{FCl} + \text{SS} \rightarrow \text{Soluble Products} \quad \ldots\ldots\ldots\ldots \quad (41)$$

$$\text{CCl} + \text{SS} \rightarrow \text{Soluble Products} \quad \ldots\ldots\ldots\ldots \quad (42)$$

The rate of SS reduction may be expressed as follows:

$$\frac{d(\text{SS})}{dt} = \text{CC2 (FCl) (SS)} + \text{CC3 (CCl) (SS)} \quad \ldots\ldots\ldots \quad (43)$$

CC2 and CC3 are rate constants. To determine if second order kinetics are actually followed, ln (chlorine/SS) was plotted versus time, using the approach described by Levenspeil (1962). This was performed for both free and combined chlorine. The results, as shown by the straight line plots in Figure 77 indicate second order reactions.

Upon performing a regression analyses, values of CC2 and CC3 were determined as shown in the following equation:

$$\frac{d(\text{SS})}{dt} = (-5.85 \times 10^{-5})\ \text{(FCl) (SS)} + (-3.5 \times 10^{-4})\text{(CCl)(SS)} \quad \ldots\ldots\ldots\ldots \quad (44)$$

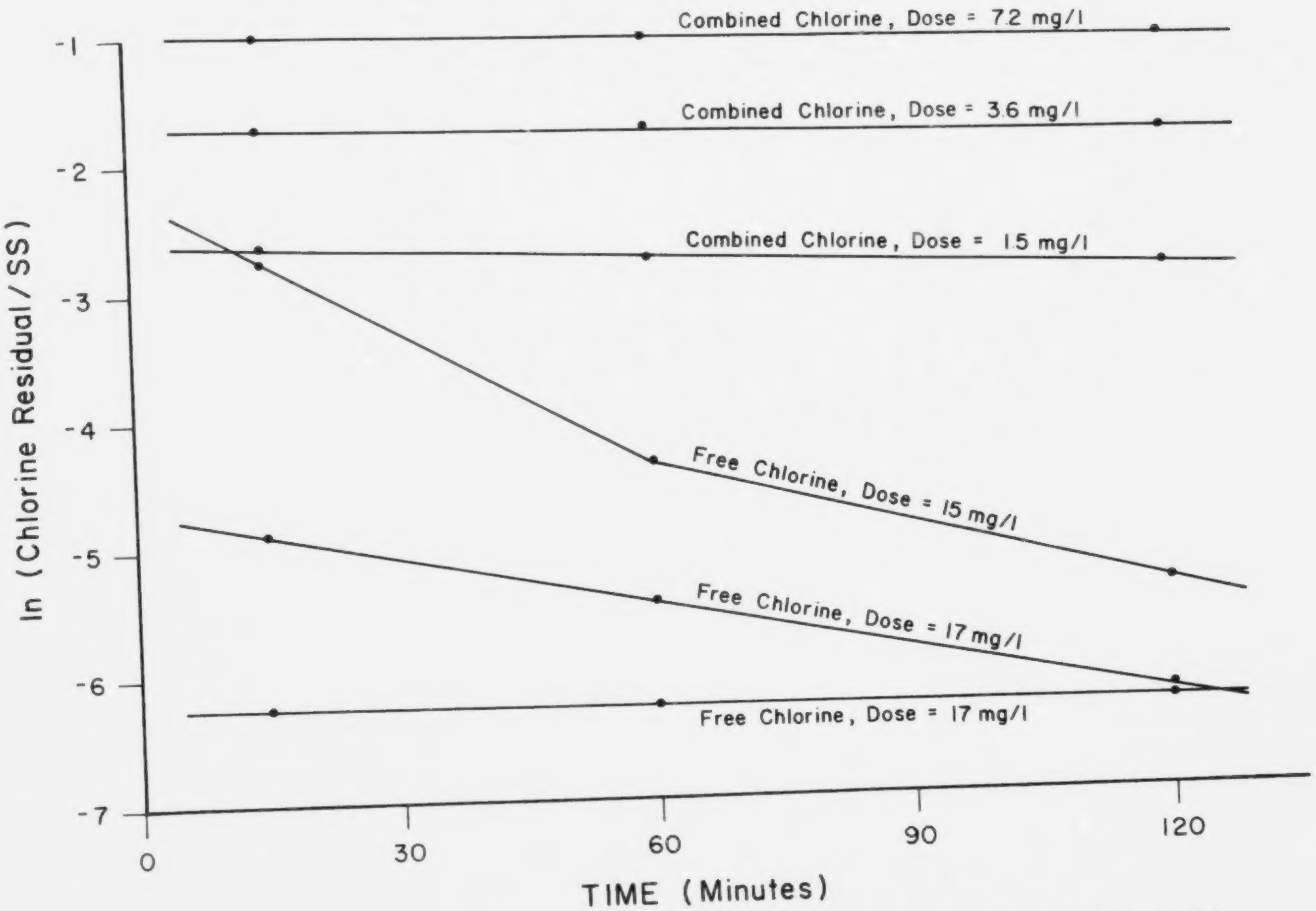


Figure 77. Determination of reaction order between chlorine residual and SS.

The rate of SS decrease is in units of mg/l-min. The correlation coefficient, R, was found to be 0.33. Although the value of R is small, significance is indicated at the 95 percent confidence level because of the large quantity of data used in performing the regression. The results indicate that combined chlorine is more important in reducing SS. Although this would seem to be very unlikely, it must be considered that since combined chlorine was observed in most of the data and free chlorine appeared in only a fraction of the data, the regression was more heavily influenced by combined chlorine residuals. Also, these values were obtained only to be used as initial estimates in calibrating CHLOR-I.

Chlorine Demand

In developing a rate expression to describe the exertion of chlorine demand, it was observed from field data that the rate at which chlorine residual was consumed was slower in filtered lagoon effluent than in unfiltered effluent. The chlorine residual remaining for particular chlorine dosages at three different residence times for both filtered and unfiltered effluent is illustrated in Figures 54 and 58, respectively. Apparently, the removal of suspended solids decreases the rate of exertion of chlorine demand. In addition to suspended organics and inorganics, it is reasonable to assume that some of the chlorine demand is exerted by soluble organics and inorganics. TCOD is used to represent these possible reactants in describing the reactions between chlorine and chlorine demanding constituents of wastewater.

In using TCOD, the exertion of chlorine demand for both free and combined chlorine may be expressed by the following reactions.

$$\text{TCOD} + \text{FCl} \rightarrow \text{Complex A} \quad \ldots\ldots \quad (45)$$

$$\text{TCOD} + \text{CCl} \rightarrow \text{Complex B} \quad \ldots\ldots \quad (46)$$

There is some difficulty in using this approach to represent the rate of exertion of chlorine demand. When chlorine reacts with TCOD, the products formed also contribute to TCOD. Therefore, the equations, as written, cannot be used to describe the chemical rates of reaction. Since TCOD does not change in these reactions, it is assumed that the reaction rate constants must therefore change. This approach is useful in explaining why the greatest exertion of chlorine demand occurs within the first few moments of contact. Since the exertion of chlorine demand is related to the initial chlorine dose, the following expressions are used to describe the rates of exertion of chlorine demand.

$$\frac{d(\text{FCl})}{dt} = \text{CC4}\left(\frac{\text{FCl}}{\text{FCl}_o}\right)^{\text{CHOCLT}} (\text{TCOD})^{\text{CTCOD}} \quad \ldots\ldots \quad (47)$$

$$\frac{d(\text{CCl})}{dt} = \text{CC5}\left(\frac{\text{CCl}}{\text{CCl}_o}\right)^{\text{CNH2CL}} (\text{TCOD})^{\text{CTCOD}} \quad \ldots\ldots \quad (48)$$

CC4 and CC5 are rate constants, and CHOCLT and CNH2CL are factors used to effectively reduce reaction rates as chlorine residual decreases with increasing time. CTCOD is a constant initially set equal to 1.0, but included in these equations as a quality factor for adjusting the importance of TCOD in exerting chlorine demand. FCl_0 and CCl_0 are initial concentrations of free and combined chlorine, respectively, after previously described steady state assumptions have been made. Values of CC4, CC5, CHOCLT, and CNH2CL were determined by assuming initial values and then adjusting them during the model calibration process to fit the data.

Disinfection

The disinfection model was developed by initially assuming that chlorine reacts with total coliforms (TC) and fecal coliforms (FC) in a manner similar to other chemical reactions. If second order kinetics are used to describe these reactions, the following rate expressions result.

$$\frac{d(TC)}{dt} = CC6\ (CCl)\ (TC) + CC7\ (FCl)\ (TC) \quad \ldots\ldots\ldots \quad (49)$$

$$\frac{d(FC)}{dt} = CC8\ (CCl)\ (FC) + CC9\ (FCl)\ (FC) \quad \ldots\ldots\ldots \quad (50)$$

CC6 to CC9 are reaction rate constants.

To determine if these reactions truly follow second order kinetics, ln (coliforms/total chlorine residual) was plotted against time for several sets of data. The results are shown in Figure 78, and suggest that the reaction kinetics are probably more complex than can be explained by second order kinetics. Since stoichiometric ratios are not known, the general chemical reactions are written as follows:

$$\mathrm{CTOTAL(TC) + BNH2CL(CCl) \rightarrow Products} \quad \ldots\ldots\ldots \quad (51)$$

$$\mathrm{CTOTAL(TC) + BHOCLT(FCl) \rightarrow Products} \quad \ldots\ldots\ldots \quad (52)$$

$$\mathrm{CFECAL(FC) + BNH2CL(CCl) \rightarrow Products} \quad \ldots\ldots\ldots \quad (53)$$

$$\mathrm{CFECAL(FC) + BHOCLT(FCl) \rightarrow Products} \quad \ldots\ldots\ldots \quad (54)$$

CTOTAL, CFECAL, BNH2CL, and BHOCLT are stoichiometric constants.

Kinetically, the rates of reactions in MPN counts/100 ml-min. are expressed by the following differential equations:

$$\frac{d(TC)}{dt} = CC6\ (TC)^{CTOTAL}\ (CCl)^{BNH2Cl} + CC7\ (TC)^{CTOTAL}\ (FCl)^{BHOCLT} \quad \ldots\ldots\ldots \quad (55)$$

$$\frac{d(FC)}{dt} = CC8\ (FC)^{CFECAL}\ (CCl)^{BNH2CL} + CC9\ (FC)^{CFECAL}\ (FCl)^{BHOCLT} \quad \ldots\ldots\ldots \quad (56)$$

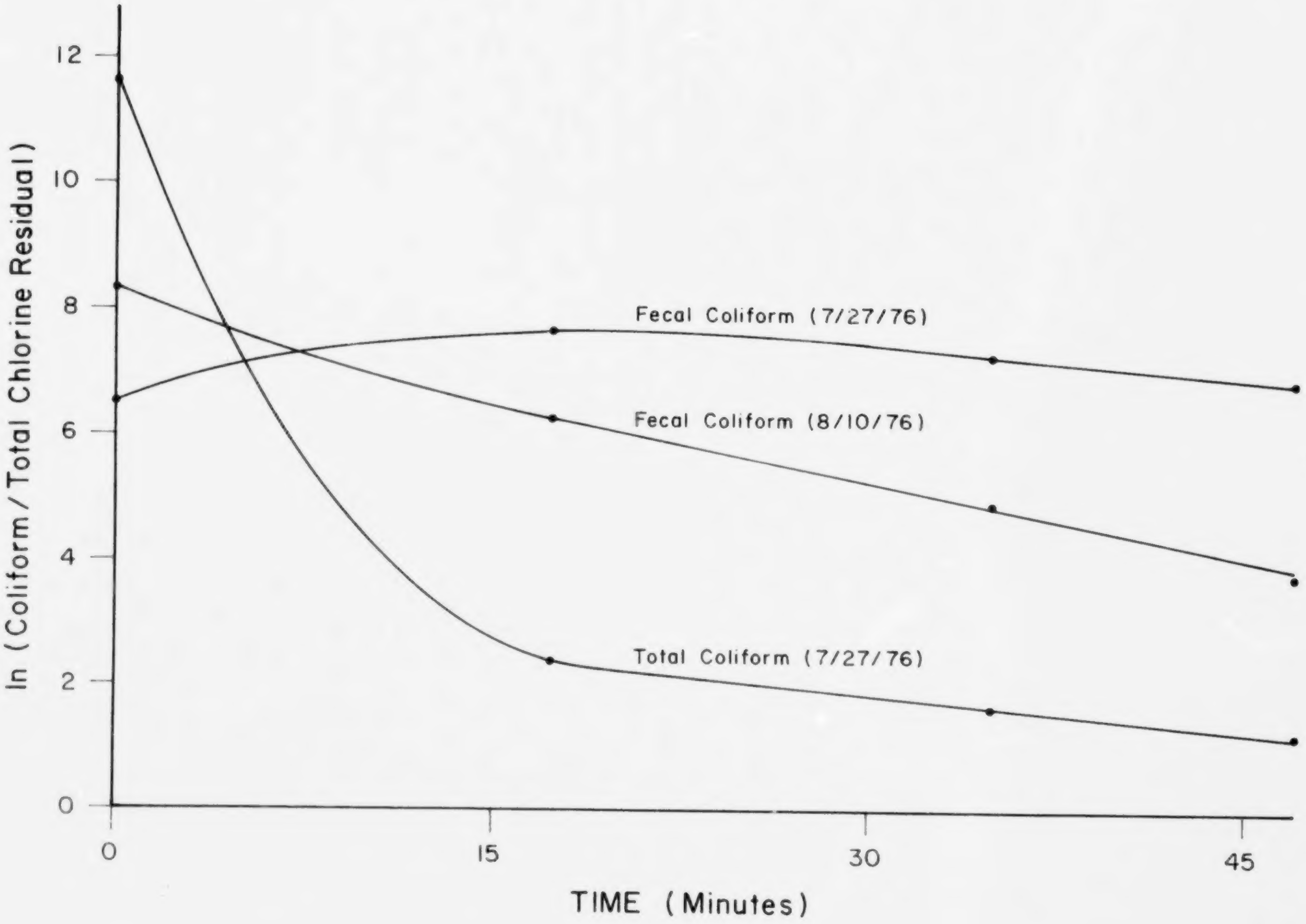


Figure 78. Determination of reaction order for total and fecal coliform reduction for three sample runs.

The rate constants, CC6 to CC9, have been found to be temperature dependent. Butterfield (1943) found that at pH 8, twice as much free chlorine is required to produce the same bacterial kill at 2-5^{o}C as at 20-25^{o}C. Butterfield and Wattie (1946) have also indicated that for combined chlorine, a coliform reduction of 99 percent requires a contact time of nine times longer or a chlorine dose of 2.5 times greater at 2.5^{o}C than at 20-25^{o}C. It was also found that at 2-6^{o}C there was little bacterial kill with less than 1.2 mg/l combined residual, while at 20-25^{o}C significant kill was observed down to 0.3 mg/l combined chlorine.

Since rate constants were found to be temperature dependent, it was necessary to separate the field data into temperature ranges in order to obtain initial values of stoichiometric and rate constants. For the 20^{o}C temperature range, regression analyses were performed to obtain initial estimates for values of the constants. These initial estimates were used as the starting point in calibrating CHLOR-I and were later adjusted for temperature by trial and error.

Temperature Dependence

Grouping of field data by temperature range and performing preliminary regression analyses reinforces what the literature indicates concerning the temperature dependence of disinfection. Preliminary inspection of data in Appendix A suggests that chlorine demand is also affected by temperature. Metcalf and Eddy, Inc. (1972) have used the Arrhenius equation, as follows, to express the effect of temperature on bacterial kill.

$$\log \frac{t_1}{t_2} = \frac{E(T_2 - T_1)}{4.58\ T_1 T_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (57)$$

In this equation, t_1 and t_2 are the times required for a specific percentage of kill at temperatures T_1 and T_2 (^{o}K), respectively, and E is the activation energy.

Weber (1972) has used the Arrhenius equation as the basis for determining the change in rate constants with temperature. When the activation energy, E, is not known, the following expression is used:

$$k_T = k_{20}\ \beta^{(T-20)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (58)$$

The rate constant at temperature T^{o}C is k_T; k_{20} is the rate constant at 20^{o}C; and β is an empirical constant. The expression was used in CHLOR-I to describe the effects of temperature on the reaction rates for disinfection and chlorine demand. Initial values of β were determined from a reference made by Reid and Carlson (1974) that the reaction rate doubles for each 10^{o}C rise in temperature. Using this approach, the value of β was determined to be 1.08. This value was used as an initial estimate and later adjusted to fit the data during model calibration.

Numerical Solution

In CHLOR-I, expressions to describe sulfide reduction, chlorine consumed by sulfide, reactions with ammonia and organic nitrogen, and breakpoint chlorination are independent of time and therefore solved algebraically. Dynamic approaches as previously discussed are used to define the changes in SCOD, SS, chlorine demand, and disinfection. The resulting system of differential equations is solved by using a general second order Runge-Kutta solution technique. Two sub-routines presented by Franks (1972) are used to give the option of using either first or fourth order solution techniques, in addition to second order. A complete listing of the computer program is present in Appendix F along with descriptions of all variables. Rate constants are expressed in mg/l-min. except for disinfection, which is in units of counts/100 ml-min. The integration time step was experimentally adjusted to 0.05 minutes. Smaller time steps were found to be unnecessary and larger time steps resulted in model instability.

Model Options

In addition to the model components of CHLOR-I as described to this point, an option was developed to replace the steady state representation of breakpoint chlorination with a more sophisticated kinetic approach. In exercising this option, the model becomes completely dynamic, with the exception of sulfide reactions. The model is not only described more accurately by the kinetic approach, but is also represented in more detail. Free chlorine is handled as HOCl and OCl^-, while combined chlorine is broken down into monochloramine and dichloramine. This reflects pH dependence. Incorporation of these model options into CHLOR-I is referred to in a different model, hereafter known as CHLOR-II. A complete computer listing of CHLOR-II, along with a description of variables, is contained in Appendix G.

Most of the kinetics used to describe breakpoint chlorination reactions have been defined and discussed by Weil and Morris (1949), Morris (1967), Wei (1972), and Wei and Morris (1974). These kinetics have been applied in a dynamic model developed by Stenstrom (1975) to describe chlorination in batch and continuous flow reactors. Since the kinetics have been discussed considerably in the literature, only a brief discussion will be presented.

The hydrolysis of chlorine gas and dissociation of hypochlorous acid, as previously discussed, are assumed to be instantaneous. The reactions between HOCl, OCl^-, NH_3, and NH_4^+ are described by the following equations:

$$NH_3 + HOCl \xrightarrow{k_1} NH_2Cl + H_2O \quad . . . . (59)$$

$$NH_4^+ + OCl^- \xrightarrow{k_1'} NH_2Cl + H_2O \quad . . . . (60)$$

In these equations, free chlorine in both its forms reacts with ammonia and ammonium. Morris (1949) has pointed this out to show that the reactions are highly pH dependent. The reaction rate constants are expressed by k_1 and k_1'. Although both equations describe the formation of monochloramine equally well, Morris (1974) has indicated that the formation of NH_2Cl is sufficiently explained by the first reaction. Using that equation, the rate of monochloramine formation (r_1) is described by

$$r_1 = k_1 [HOCl][NH_3] \quad (61)$$

in which [ ] denotes molar concentrations.

The value of the rate constant, k_1, is expressed by Morris (1974) as

$$k_1 = 9.7 \times 10^8 e^{(-3000/RT)} \quad (62)$$

in which T is temperature in °K and R is the universal gas constant (1.99 cal/°K-gmole). At 25°C, k_1 is 5.1 x 10^6 l/mole-sec. The magnitude of the rate constant indicates how rapidly monochloramine is formed.

The reaction describing dichloramine formation is as follows:

$$NH_2Cl + HOCl \xrightarrow{k_2} NHCl_2 + H_2O \quad (63)$$

The reaction rate, r_2, is expressed by

$$r_2 = k_2[NH_2Cl][HOCl] \quad (64)$$

The rate constant, k_2, is also temperature dependent and is calculated by Morris (1967) from

$$k_2 = 7.6 \times 10^7 e^{(-7300/RT)} \quad (65)$$

At 25°C, k_2 has a value of 3.4 x 10^2 l/mole-sec. It has also been found by Morris (1967) that the reaction is catalyzed in the presence of hydrogen ion concentrations $[H^+]$ and acetic acid [HAC]. The catalyzed rate constant is expressed by

$$k_{2(catalyzed)} = k_2(1 + [H^+] + [HAC]) \quad (66)$$

An additional reaction of interest is the formation of nitrogen trichloride. This is expressed in the following reaction:

$$HOCl + NHCl_2 \rightleftarrows NCl_3 + H_2O \quad (67)$$

However, since this reversible reaction predominates to the right only below pH 4.4, it is considered to be relatively unimportant in chlorination of waste stabilization lagoon effluent. Therefore, rate expressions for this reaction are not included in CHLOR-II.

The overall reaction for breakpoint chlorination is described by Wei and Morris (1974) by the following reaction:

$$2NH_2Cl + HOCl \rightarrow N_2\uparrow + H_2O + 3H^+ + 3Cl^- \quad (68)$$

In developing the mechanisms for this reaction, a basic mechanism proposed by Chapin (1931) is used. This reaction is as follows:

$$NHCl_2 + H_2O \xrightarrow{k_3} NOH + 2H^+ + 2Cl^- \quad (69)$$

The nitroxyl group, NOH, is an intermediate product. Wei (1972) and Wei and Morris (1974) have hypothesized that NOH reacts with $NHCl_2$, NH_2Cl, and HOCl as described by the following reactions:

$$NOH + NHCl_2 \xrightarrow{k_4} N_2 + HOCl + H^+ + Cl^- \quad (70)$$

$$NOH + NH_2Cl \xrightarrow{k_5} N_2 + H_2O + Cl^- + H^+ \quad (71)$$

$$NOH + 2HOCl \xrightarrow{k_6} NO_3^- + 3H^+ + 2Cl^- \quad (72)$$

Values for the rate constants k_3 to k_6 were determined experimentally by Morris and Wei (1969) or calculated from their work by Stenstrom (1975). These values at 20°C and pH 7 are as follows:

$$k_3 = 0.05 \text{ 1/mole-sec} \quad (73)$$

$$k_4 = 1.0 \times 10^6 \text{ 1/mole-sec} \quad (74)$$

$$k_5 = 2.0 \times 10^7 \text{ 1/mole-sec} \quad (75)$$

$$k_6 = 4.26 \times 10^7 \text{ 1/mole-sec} \quad (76)$$

The rate expressions for these breakpoint reactions are described in the following equations

$$r_3 = k_3 [NHCl_2] \quad (77)$$

$$r_4 = k_4 [NOH] [NHCl_2] \quad (78)$$

$$r_5 = k_5 [NOH] [NH_2Cl] \quad (79)$$

$$r_6 = k_6 [NOH] [HOCl]^2 \quad (80)$$

In all of the previous equations, [ ] refers to molar concentrations, HOCl refers to unionized hypochlorous acid, and NH_3 refers to unionized ammonia. To determine the distribution of ionized and unionized hypochlorous acid, the following equation is used:

$$HOCl = \frac{[H^+][HOCl_{Total}]}{K_{HOCl} + [H^+]} \quad (81)$$

$HOCl_{Total}$ is the sum of HOCl and OCl^-. K_{HOCl} is the equilibrium constant. The distribution between ammonia and ammonium is determined by the following:

$$NH_3 = \frac{[OH^-][NH_{3_{Total}}]}{K_{NH_3} + [OH^-]} \quad . . . . (82)$$

$NH_{3_{Total}}$ is the sum of NH_3 and NH_4^+. K_{NH_3} is the equilibrium constant. Values of K_{HOCl} and K_{NH_3} are adjusted for temperature between 0-25°C. From data presented by Metcalf and Eddy, Inc. (1972) and Weber (1972) at 20°C, K_{HOCl} is 2.62×10^{-8} and K_{NH_3} is 1.71×10^{-3}.

From the rate expressions previously described, the following differential equations were developed to determine the rates of change in concentrations of key chemical constituents.

$$\frac{d[HOCl_{Total}]}{dt} = -r_1 - r_2 + r_4 - r_6 \quad . . . . (83)$$

$$\frac{d[NH_{3_{Total}}]}{dt} = -r_1 \quad . . . . (84)$$

$$\frac{d[NH_2Cl]}{dt} = r_1 - r_2 - r_5 \quad . . . . (85)$$

$$\frac{d[NHCl_2]}{dt} = r_2 - r_3 - r_4 \quad . . . . (86)$$

$$\frac{d[NOH]}{dt} = r_3 - r_4 - r_5 - r_6 \quad . . . . (87)$$

$$\frac{d[NO_3^-]}{dt} = r_6 \quad . . . . (88)$$

In the model developed by Stenstrom (1975), differential equations were also used to describe rates of disinfection and chlorine demand. The rate constants for these reactions were calculated from data presented in the literature. However, they are only applicable to highly treated wastewater. Therefore, the rate expressions developed in CHLOR-I to describe disinfection and chlorine demand, as well as SS and SCOD changes, are also used in CHLOR-II.

The numerical solution for CHLOR-II also utilizes a second order Runge-Kutta technique with some modification from that used for CHLOR-I. However, because of the mixture of extremely rapid reactions with relatively slow reactions, the solution technique is extremely sensitive. Rate constants are in units of seconds, rather than minutes, and concentrations in units of moles/l, rather than mg/l as used in CHLOR-I. As a result of the rapid reactions in CHLOR-II, it is necessary to use an extremely small time step in obtaining a solution. It was found by trial and error that for most data an initial time step of 0.002 seconds was necessary to prevent instability. The additional computer time necessary to obtain a solution is a serious disadvantage of CHLOR-II, particularly when most of the time it is unnecessary to calculate solutions for those reactions involved in breakpoint chlorination.

In an effort to improve the efficiency of CHLOR-II, a step optimization subroutine, as described by Gear (1971), was incorporated in the model. A listing of this subroutine is found in Appendix G. The objective of the subroutine is to keep the error below a specified minimum while allowing the step size to get as large as possible. Step optimization is brought into action every fifth time to appraise the maximum allowable size of the integration time step. As time increases, the stability of the model also increases and the rate at which the step size is adjusted also increases.

MODEL CALIBRATION

Since most of the field data collected for this study does not involve breakpoint chlorination, the primary objective of model calibration was to determine values of rate constants and other coefficients used in CHLOR-I for all conditions except breakpoint. Secondary objectives involve the calibration of the steady state breakpoint assumptions used in CHLOR-I and a comparison between how well CHLOR-I and CHLOR-II describe breakpoint chlorination.

Because of the large amount of data collected and the computer time involved in making each solution, it was impractical to use all of the field data to calibrate the model. Therefore, to reduce the data to representative samples, all of the data were grouped into similar ranges of coliform, TCOD, NH_3-N, temperature, and chlorine dose, and then averaged. The groups which contained the most replications and also represented the extreme initial conditions of temperature, chlorine dose, coliform concentrations, etc. were selected as the unfiltered data to be used for calibration. Six groups representing chlorine doses of 1, 2, 3, 4, 5, and 7 mg/l chlorine and a temperature range of 4.0 - 22°C, were selected as the calibration data. The number of replications from all groups represented approximately 5 percent of the total data.

The correlation coefficient, R , was selected as the objective function in determining how well predicted values compared with observed data. Four key parameters, free and combined chlorine residual and total and fecal coliforms, were selected to calculate the correlation coefficients. Other parameters were observed, although they were considered to be of less importance in calibrating the model. Coefficients were adjusted and correlation coefficients calculated until the sum of the correlation coefficients for all key parameters and all six sets of calibration data were maximized. Initial estimates of the values of coefficients were obtained from regression analyses performed as previously described. The coefficients were then adjusted one at a time by trial and error until predicted values compared favorably with observed data.

The results of the calibration of total and fecal coliforms for the six sets of calibration data are shown graphically in Figures 79-85. For all but one of the sets of data, the correlation coefficient, R , was above 0.92 indicating significance at the 99 percent confidence level. The predicted values were within the ranges specified for the MPN test at the 95 percent confidence level for all but one of the data points. For this set of calibration data, free chlorine was not produced. Therefore, the calibration was restricted to combined chlorine residual. The results of the calibration for combined

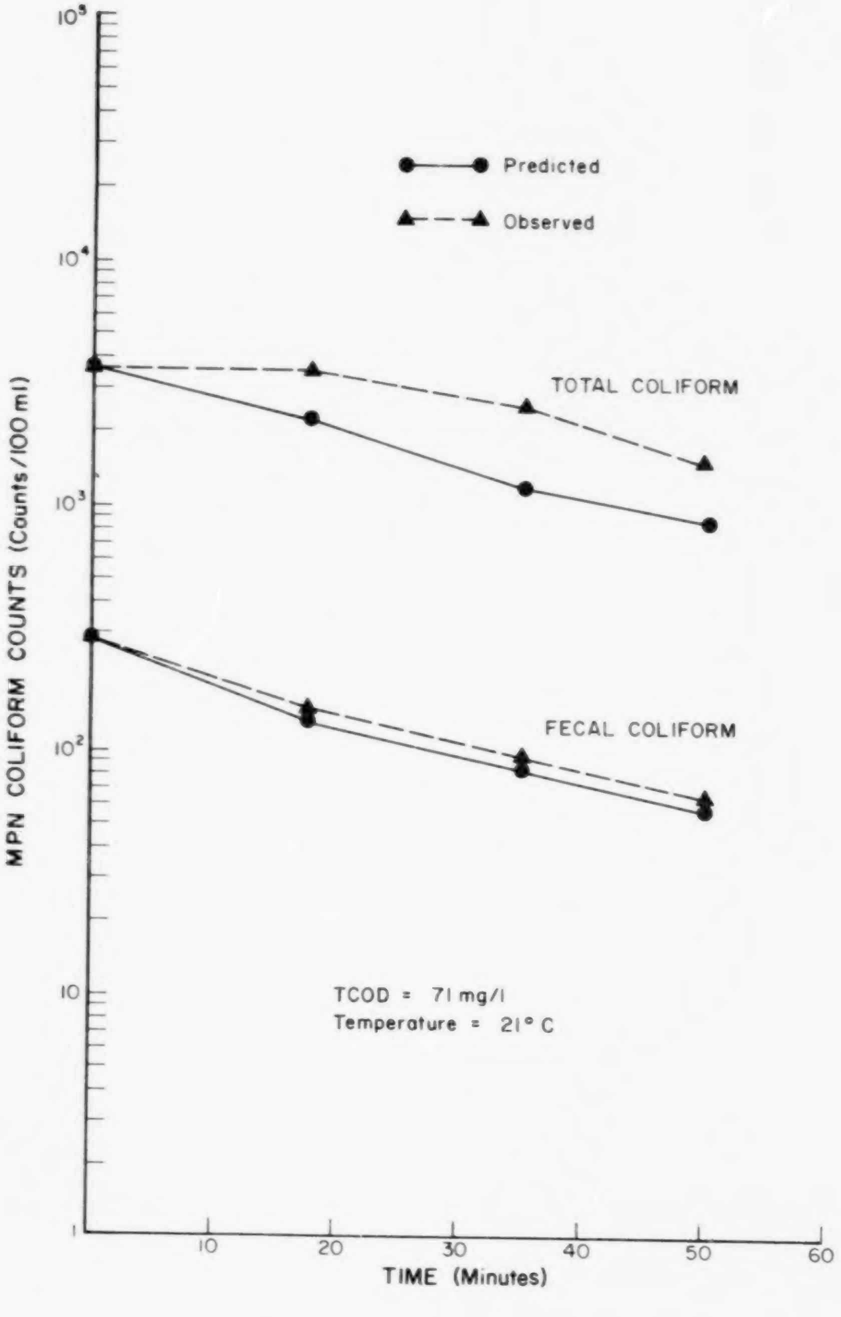


Figure 79. Calibration of CHLOR-I for a chlorine dose of 1.0 mg/l.

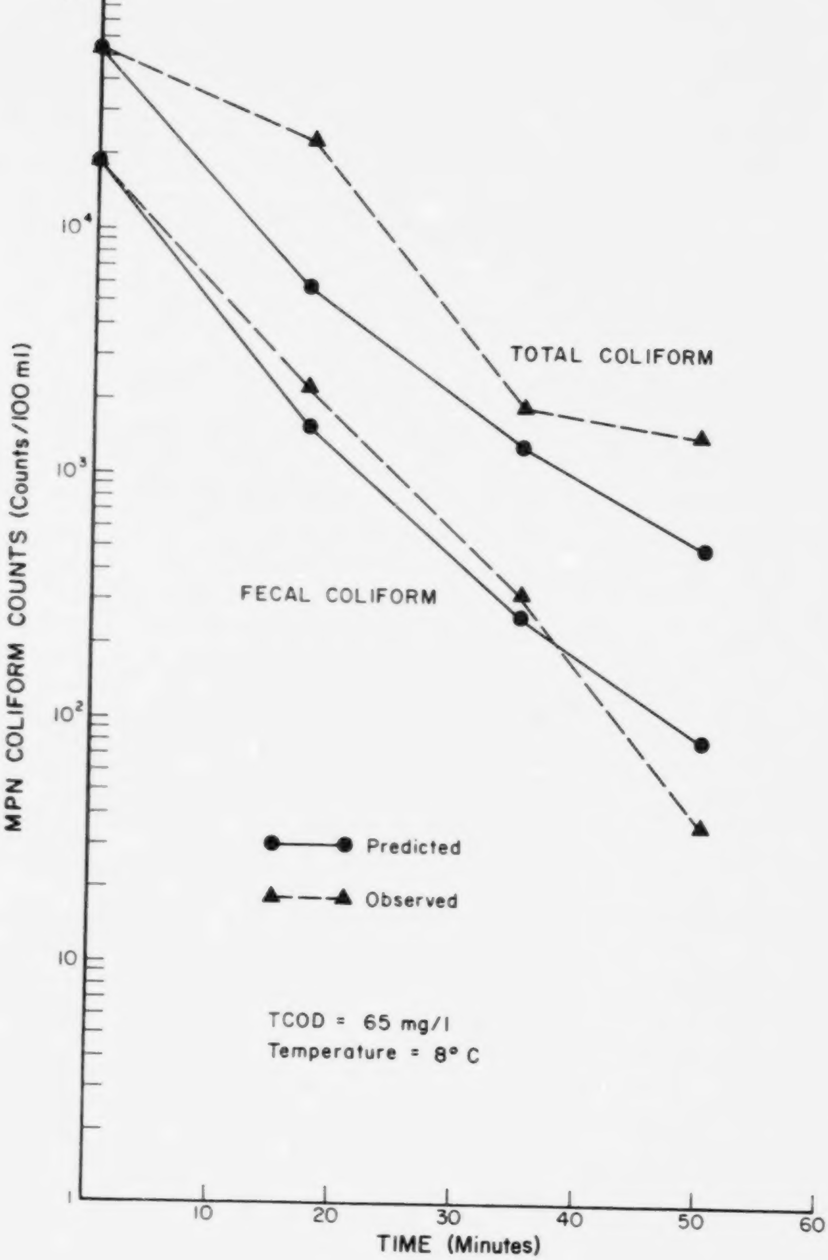


Figure 80. Calibration of CHLOR-I for a chlorine dose of 2.0 mg/1.

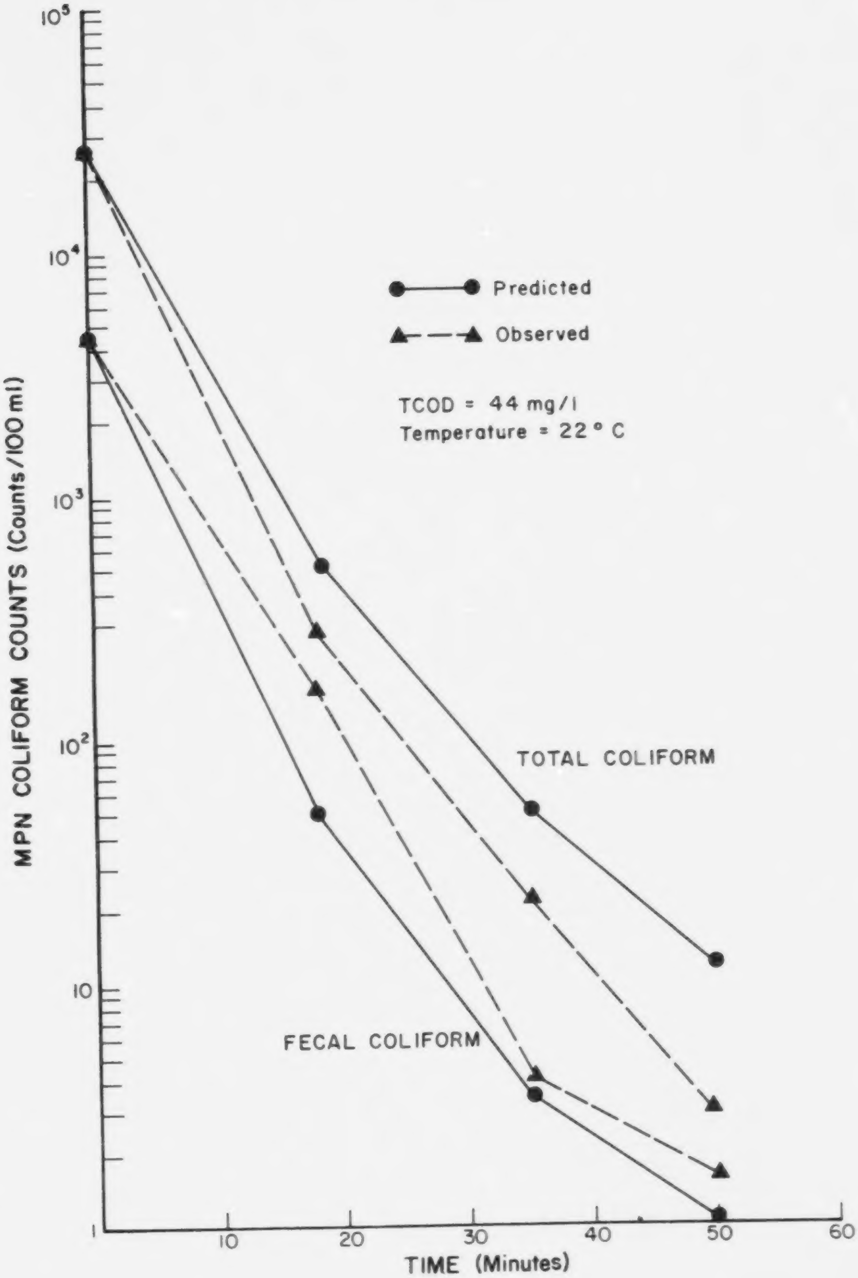


Figure 81. Calibration of CHLOR-I for a chlorine dose of 3.0 mg/l.

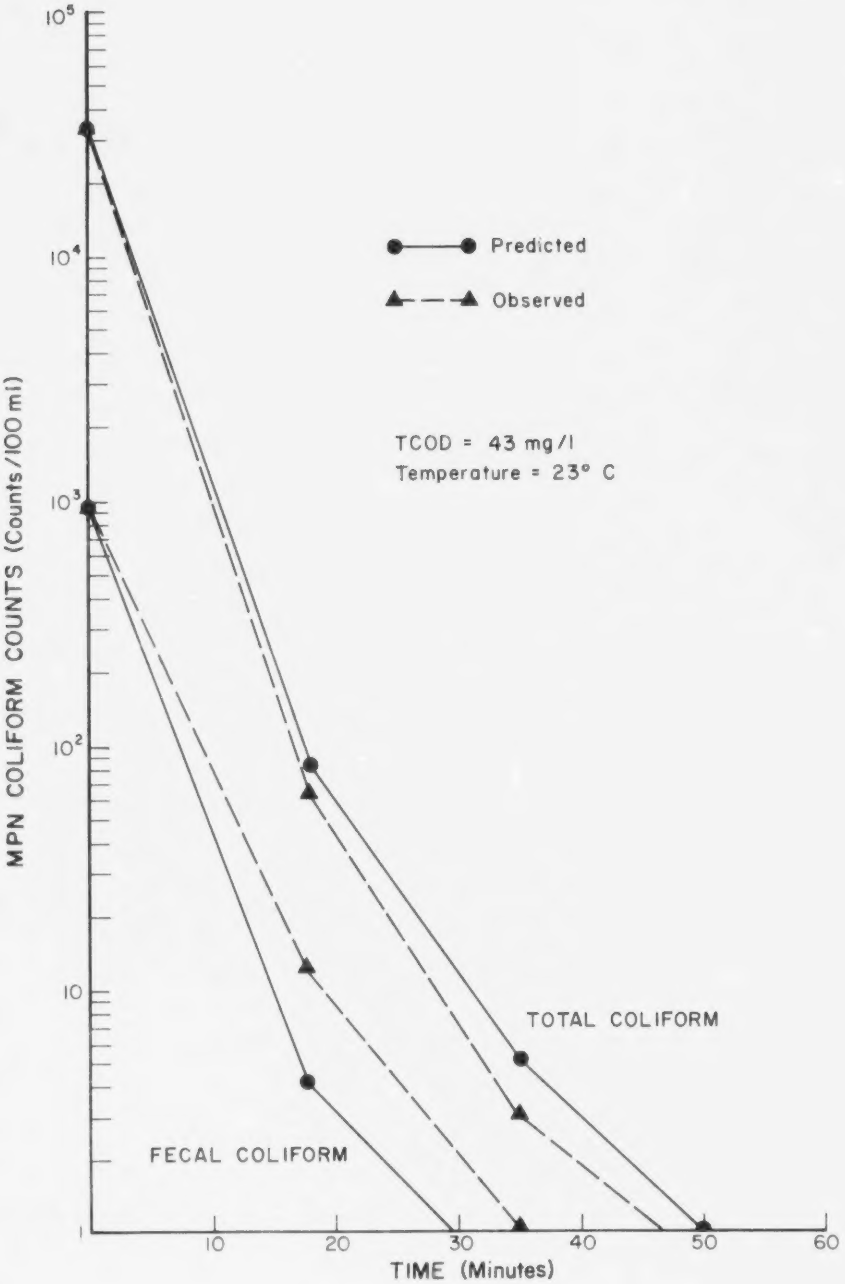


Figure 82. Calibration of CHLOR-I for a chlorine dose of 4.0 mg/1.

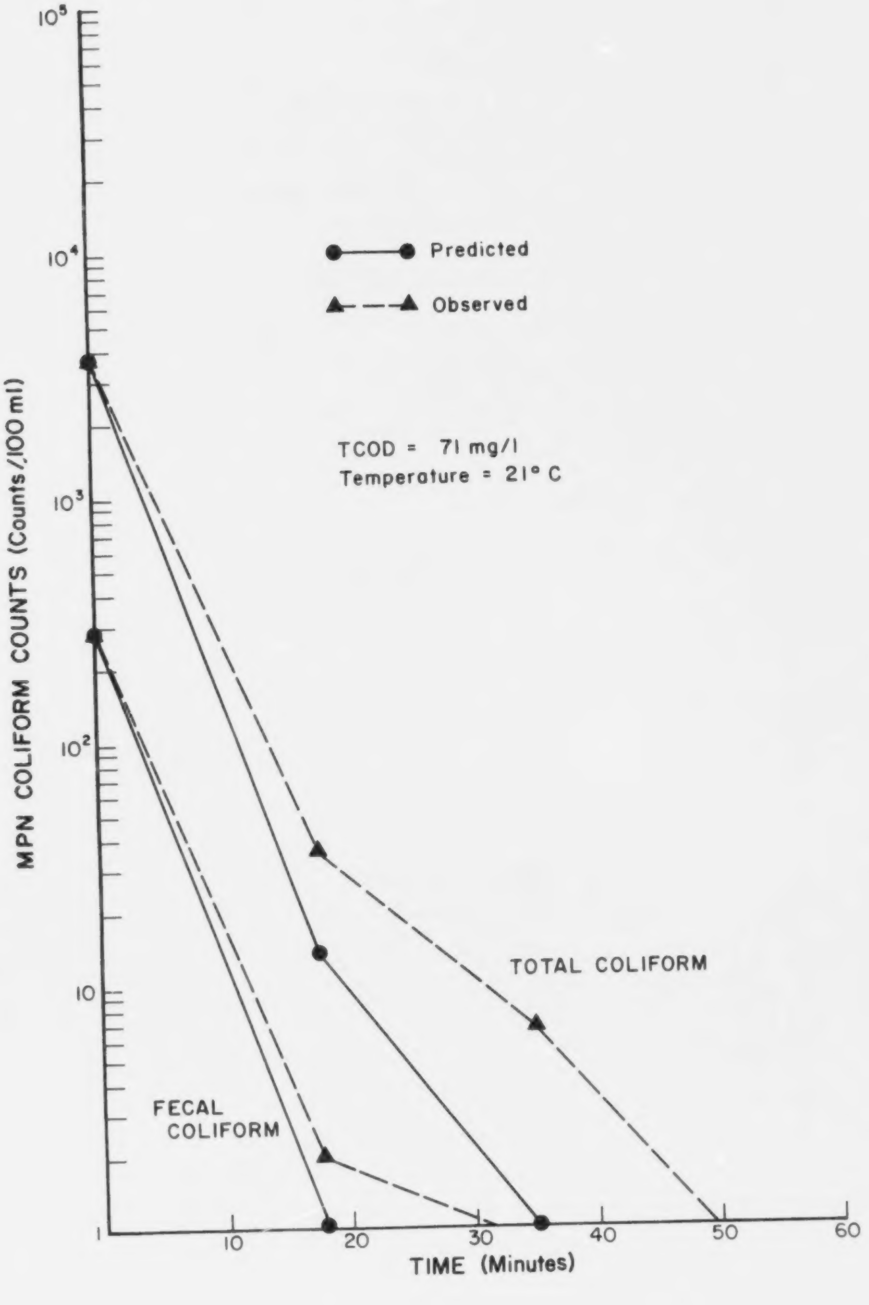


Figure 83. Calibration of CHLOR-I for a chlorine dose of 5.0 mg/l.

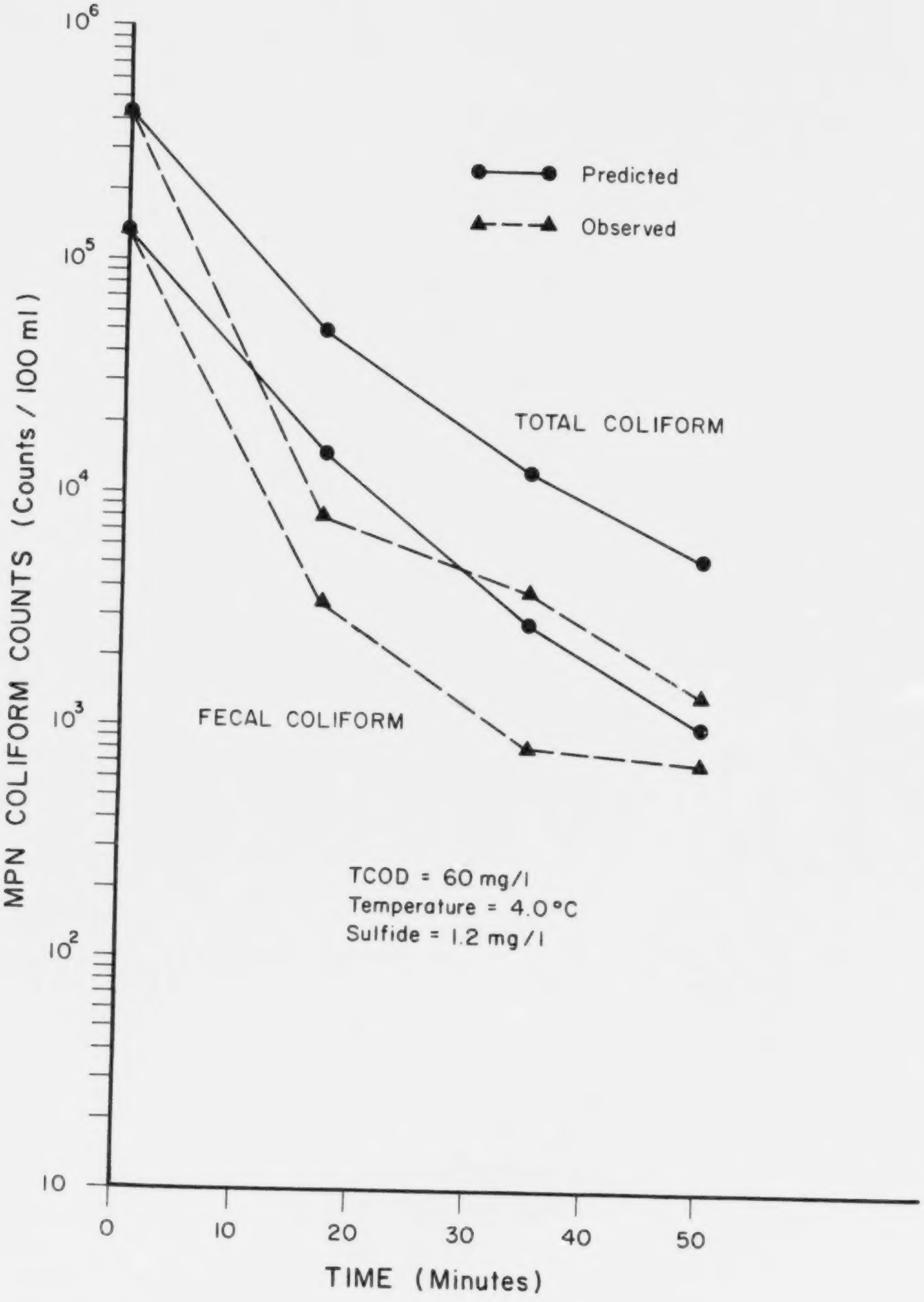


Figure 84. Calibration of CHLOR-I for a chlorine dose of 7.0 mg/l.

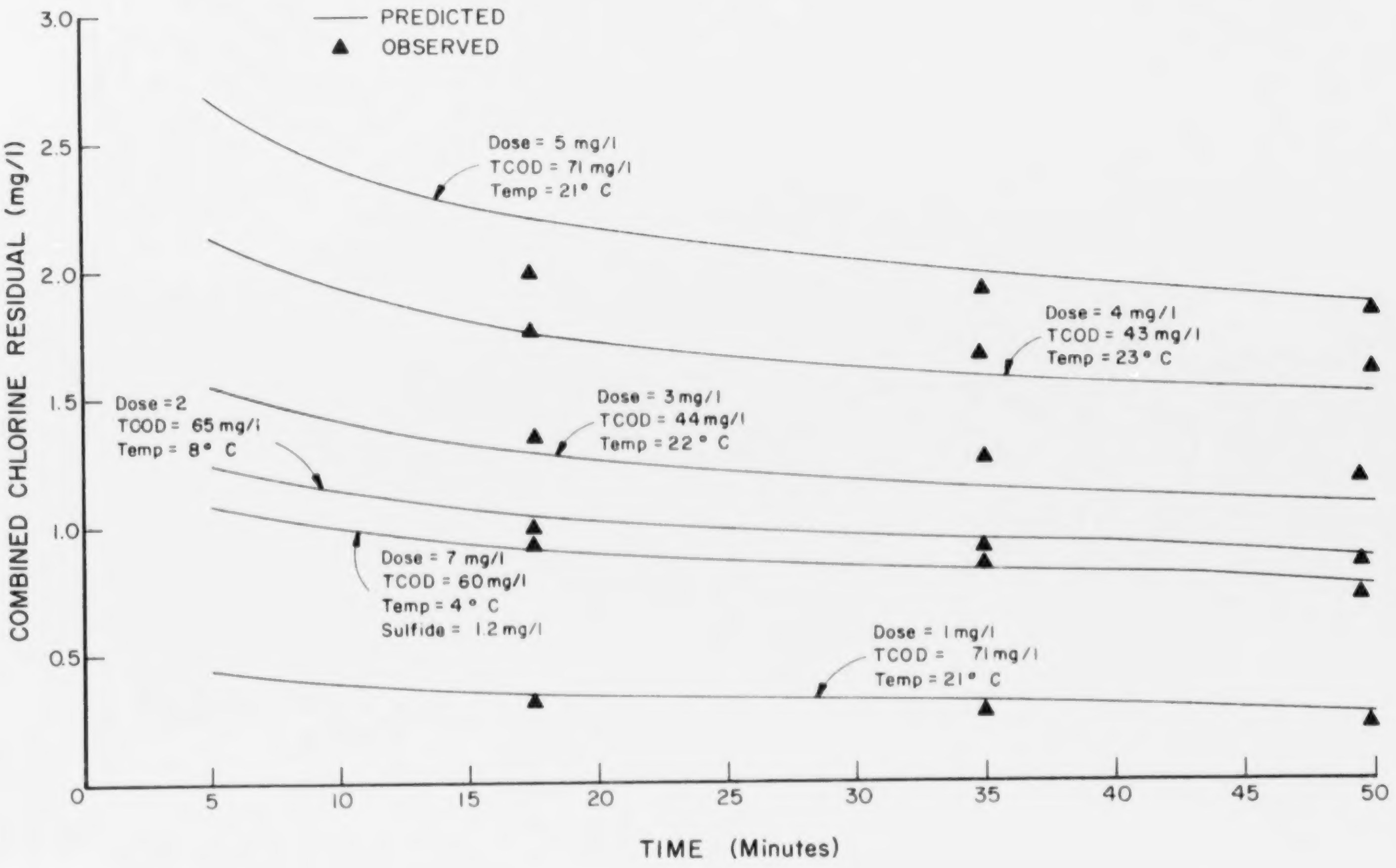


Figure 85. Calibration of CHLOR-I for combined chlorine.

chlorine are shown in Figure 85. All correlation coefficients were above 0.92 and were significant at the 99 percent confidence level.

For NH_3-N and SCOD, the model indicated no changes in concentrations. The observed data show only slight changes and these were too small to distinguish from experimental error. For sulfide, there was only one piece of calibration data which had an initial sulfide concentration. This was for the chlorine dose of 7.0 mg/l. The model predicted a reduction from 1.2 mg/l to 0.5 mg/l sulfide. The observed data show that sulfide decreased from 1.2 to 0.3 mg/l. Changes in SS were highly variable and dependent upon the settling fraction, F. F is not a constant for all data and was found to vary considerably for the calibration data. This is because the value of F is a function of the quality, as well as quantity, of SS. As an example of the correspondence between predicted and observed values of SS, three sets of data having a settling fraction set at 0.10, are presented in Figure 86.

In determining the values of coefficients associated with free chlorine or with breakpoint chlorination, four sets of field data were selected for evaluation. The coefficients were adjusted and predicted values compared with observed data. The results are presented in Table 7. It is observed that although the model predicts reasonably well for ammonia and combined chlorine, there is a great deal of variation between predicted and actual values of free chlorine. The difficulty in fitting free chlorine is partially associated with two coefficients. The organic nitrogen correction factor, CORNH3, was found to be extremely variable as indicated in Table 7. These values were determined by adjusting CORNH3 until the combined chlorine residual compared reasonably well with actual data. At that point, the resulting correspondence between predicted and actual free chlorine was observed. The other coefficient to lend difficulties was CHOCLT, a coefficient related to the rate of exertion of free chlorine demand. No value of CHOCLT was found which explained all the changes in free chlorine concentrations. Therefore, a value representing average changes was selected. Limited free chlorine data, coupled with the lack of knowledge concerning the exertion of free chlorine demand, limits the model in adequately representing changes in free chlorine.

To determine if the model options contained in CHLOR-II are better able to describe breakpoint chlorination, the model was compared with CHLOR-I. This was done by selecting a set of field data and adjusting the coefficients in CHLOR-I until predicted and observed values compared favorably. Those coefficients were then used in CHLQR-II. Since most of the breakpoint reactions take place rather rapidly, it was not necessary to use CHLOR-II to calculate predicted values for the entire time period. The evaluation of CHLOR-II was made by interfacing CHLOR-II with CHLOR-I. During the first few minutes of reaction, CHLOR-II was used to calculate concentrations of chemical constituents. When the rates of changes in those constituents involved in breakpoint reactions began to slow down, the dynamic portion of CHLOR-I was used to calculate solutions for the remainder of the time period. The results of interfacing the two models in comparison with using CHLOR-I only and with observed data are presented in Table 8.

These results indicate that there is no advantage in using the completely dynamic model to represent breakpoint chlorination for lagoon effluents. The

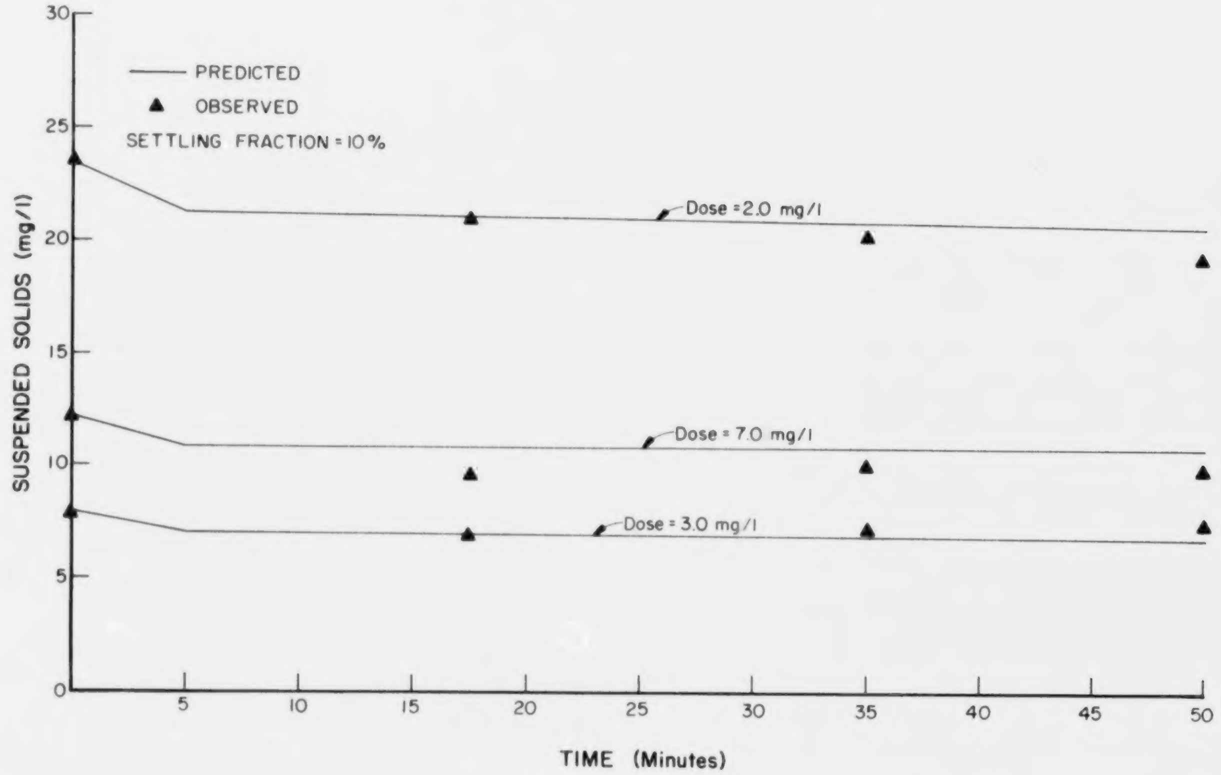


Figure 86. Relationship between observed and CHLOR-I predicted values of suspended solids concentrations.

TABLE 7. FLUCTUATIONS OF THE ORGANIC NITROGEN CORRECTION FACTOR (CORNH3) FOR DATA WHERE BREAKPOINT KINETICS APPLY

Date	Parameter	CORNH3	Time (Minutes)			
			0	17.6	35.0	49.6
8-26-75	Free Chlor. (mg/l)	3.50	10.0	0.43[a] [1.35][b]	0.39 [1.25]	0.37 [1.10]
	Comb. Chlor. (mg/l)			2.57 [5.20]	2.29 [5.35]	2.16 [5.40]
	NH_3-N (mg/l)		0.40	0 [0.25]	0 [0.33]	0 [0.21]
5-27-76	Free Chlor. (mg/l)	1.00	20.0	5.20 [11.01]	4.67 [10.22]	4.42 [9.94]
	Comb. Chlor. (mg/l)			2.22 [2.26]	2.00 [1.82]	1.89 [1.65]
	NH_3-N (mg/l)		0.97	0 [0.33]	0 [0.50]	0 [0.23]
6-1-76	Free Chlor. (mg/l)	2.50	20.0	5.30 [6.65]	4.76 [6.60]	4.50 [6.70]
	Comb. Chlor. (mg/l)			3.20 [3.18]	2.87 [3.12]	2.72 [2.80]
	NH_3-N (mg/l)		0.57	0 [0.06]	0 [0.20]	0 [0.09]
8-24-76	Free Chlor. (mg/l)	0.70	30.0	4.22 [0.55]	3.82 [0.35]	3.61 [0.25]
	Comb. Chlor. (mg/l)			2.58 [2.66]	2.31 [2.54]	2.18 [2.14]
	NH_3-N (mg/l)		2.03	0 [0.12]	0 [0.04]	0 [0.02]

[a] Predicted values.

[b] Observed values.

probable reason for this is that breakpoint kinetics, as presently defined, are not necessarily applicable in wastewater containing high concentrations of nitrogenous organics. On the other hand, there are several disadvantages in using CHLOR-II. One of these is that CHLOR-II requires considerably more computer time in obtaining solutions. Also, the model is highly sensitive to differences in input data. The model may work for one set of data, while failing to apply for another set. The size of the integration time steps and maximum permissible error is also somewhat variable and is reflected in the sensitivity of the model.

TABLE 8. COMPARISON OF CHLOR-I AND CHLOR-II AS DESCRIBING BREAKPOINT CHLORINATION

		Time (Minutes)										
		0	5	10	15	20	25	30	35	40	45	50
Free Chlor.	O	30.0	-	-	0.55	-	-	-	0.35	-	-	0.25
	I	30.0	1.50	0.96	0.74	0.61	0.53	0.47	0.42	0.39	0.36	0.33
	II	30.0	4.02	2.62	2.02	1.68	1.45	1.29	1.16	1.07	0.99	0.92
Comb. Chlor.	O	0	-	-	2.66	-	-	-	2.54	-	-	2.14
	I	0	3.12	2.81	2.64	2.52	2.43	2.36	2.31	2.26	2.22	2.19
	II	0	1.98	1.77	1.66	1.59	1.54	1.49	1.46	1.43	1.40	1.38
NH_3-N	O	2.03	-	-	0.12	-	-	-	0.04	-	-	0.02
	I	2.03	0	0	0	0	0	0	0	0	0	0
	II	2.03	0	0	0	0	0	0	0	0	0	0
Fecal Coli	O	940	-	-	2	-	-	-	0	-	-	0
	I	940	0	0	0	0	0	0	0	0	0	0
	II	940	0	0	0	0	0	0	0	0	0	0
Total Coli	O	13000	-	-	2	-	-	-	0	-	-	0
	I	13000	1.2	0.1	0	0	0	0	0	0	0	0
	II	13000	0	0	0	0	0	0	0	0	0	0
SS	O	45.10	-	-	23.24	-	-	-	23.10	-	-	22.35
	I	45.10	26.79	26.58	26.40	26.22	26.06	25.90	25.74	25.60	25.45	23.31
	II	45.10	26.88	26.74	26.63	26.52	26.43	26.34	26.25	26.18	26.10	26.03
SCOD	O	38.60	-	-	43.85	-	-	-	39.84	-	-	41.15
	I	38.60	39.21	39.45	39.62	39.76	39.87	39.98	40.07	40.15	40.23	40.30
	II	38.60	40.08	40.73	41.19	41.56	41.86	42.13	42.37	42.59	42.79	42.98

O = Observed results
I = CHLOR-I; settling fraction, F, = 0.40; CORNH3 = 0.70.
II = Interface of CHLOR-I and CHLOR-II.

Although CHLOR-II was not found to be particularly applicable to this set of waste stabilization lagoon data, it has been discussed here in the event that it may find application to other systems for which breakpoint chlorination is more likely to occur. Remaining discussions of the chlorination model are restricted to CHLOR-I. A listing of the values for the coefficients obtained from the calibration of CHLOR-I are contained in Table 9. A description of these variables is found in Appendix F.

MODEL SENSITIVITY ANALYSIS

A sensitivity analysis was performed on one set of data to show the effects of variations in key coefficients on predicted results. This was done

TABLE 9. VALUES OF COEFFICIENTS USED IN CHLOR-I

Coefficient[a]	Values	
SRATIO	3.6	
TADJ	1.03	
TADJ2	1.15	
CORNH3	0.70 - 3.50	
F	0.10 - 0.50	
CHOCLT	7.4	
CTCOD	1.00	
CNH2CL	7.4	
CTOTAL	1.10	
CFECAL	1.08	
BHOCLT	1.30	
BNH2CL	1.35	
CC1	7.24×10^{-4}	l/mg-min
CC2	-5.00×10^{-4}	l/mg-min
CC3	-5.00×10^{-4}	l/mg-min
CC4	-0.20	l/mg-min
CC5	-0.10	l/mg-min
CC6	-0.055	l/mg-min
CC7	-0.20	l/mg-min
CC8	-0.085	l/mg-min
CC9	-0.35	l/mg-min

[a] Refer to Appendix F for definition of terms.

by increasing and decreasing the values of coefficients obtained from calibration by specified percentages. When the coefficients CC6 and CC8 were varied by ± 25 percent, the effects on total and fecal coliform as shown in Figure 87 resulted. BNH2CL and BHOCLT were varied by ± 10 percent. The resulting coliform variations are shown in Figure 88. CTOTAL and CFECAL were also varied by ± 10 percent. The results are shown in Figure 89. When CC5 was varied by ± 50 percent, as shown for coliform reduction in Figure 90, the combined chlorine residual was also varied. Results showing these chlorine residual fluctuations are shown in Figure 91. Likewise, the variation of CHOCLT and CNH2CL by ± 10 percent produced fluctuations in both coliform reduction and in the chlorine residual remaining. Results for total and fecal coliform reduction and for the exertion of chlorine demand are shown in Figures 92 and 93 respectively.

The temperature adjustment coefficients of TADJ and TADJ2 were also varied. These coefficients were varied by ± 5 percent. For TADJ, the results for coliform reduction at 22°C and 5°C are shown in Figures 94 and 95. Fluctuations in TADJ2 for coliform reductions at 22°C and 5°C are shown in Figures 96 and 97. The effects of varying this coefficient on chlorine residual are shown in Figures 98 and 99 for the same two temperatures.

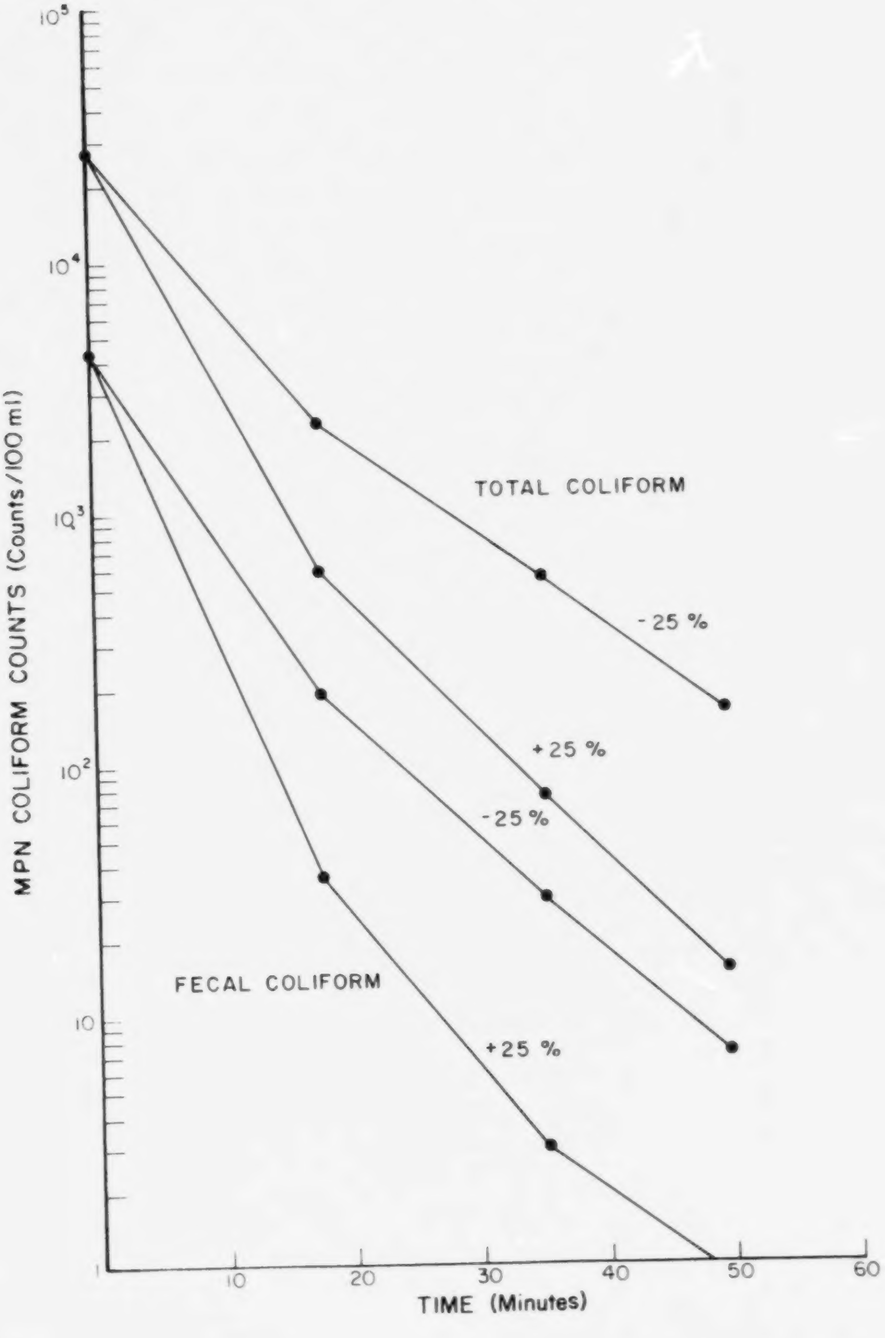


Figure 87. Variation of coliform MPN with fluctuations of CC6 and CC8 by ± 25 percent.

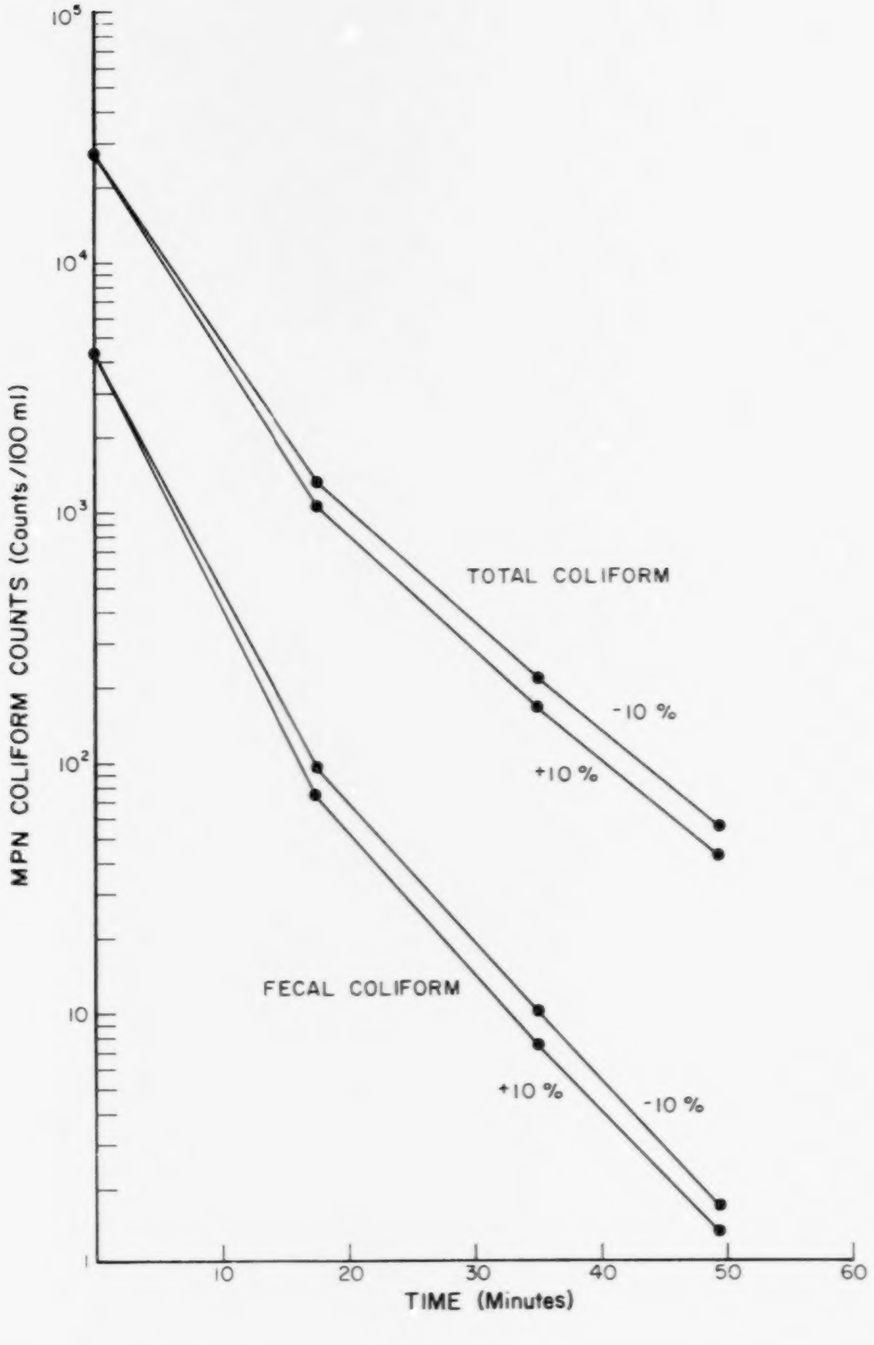


Figure 88. Variation of coliform MPN with fluctuations of BNH2CL and BHOCLT by ± 10 percent.

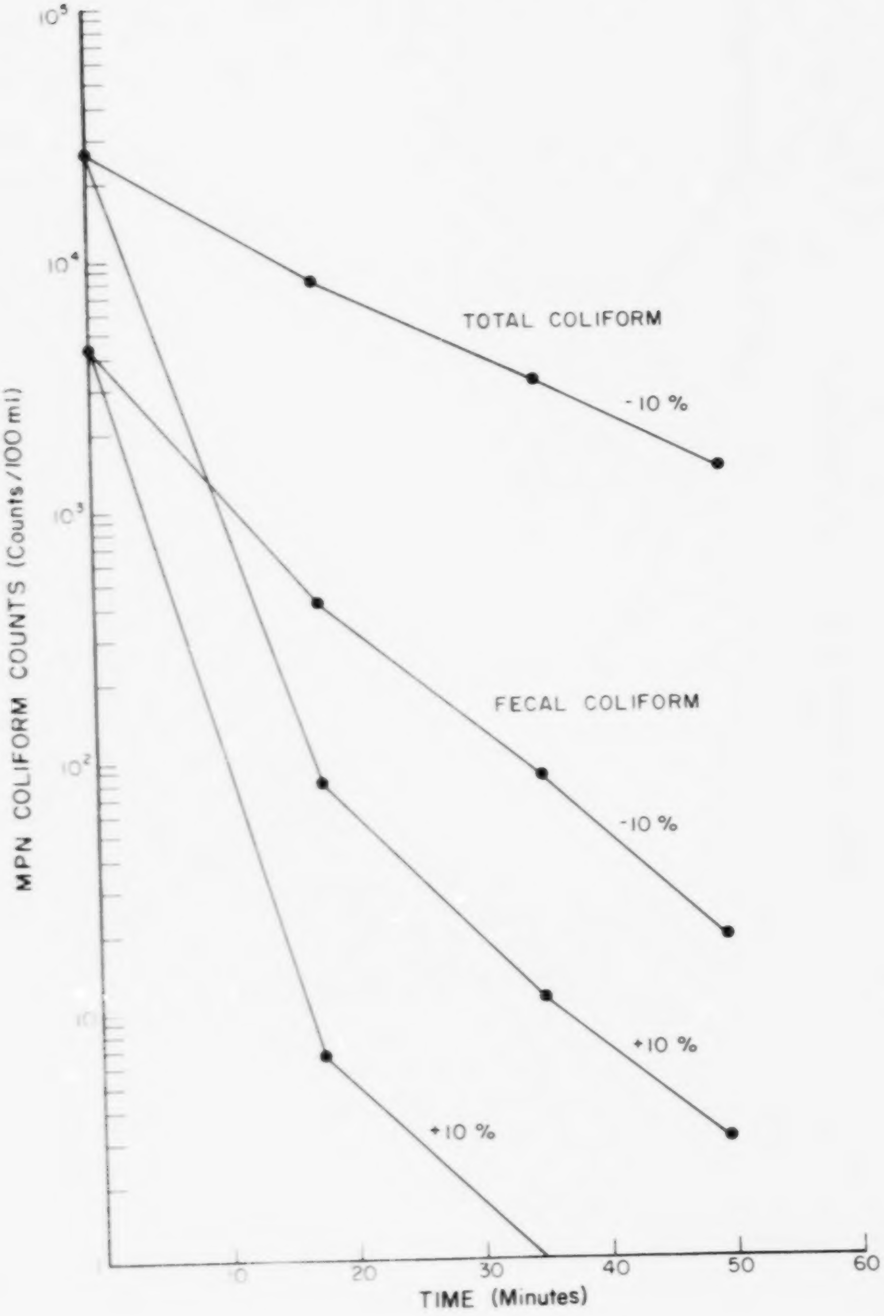


Figure 89. Variation of coliform MPN with fluctuations of CTOTAL and CFECAL by ± 10 percent.

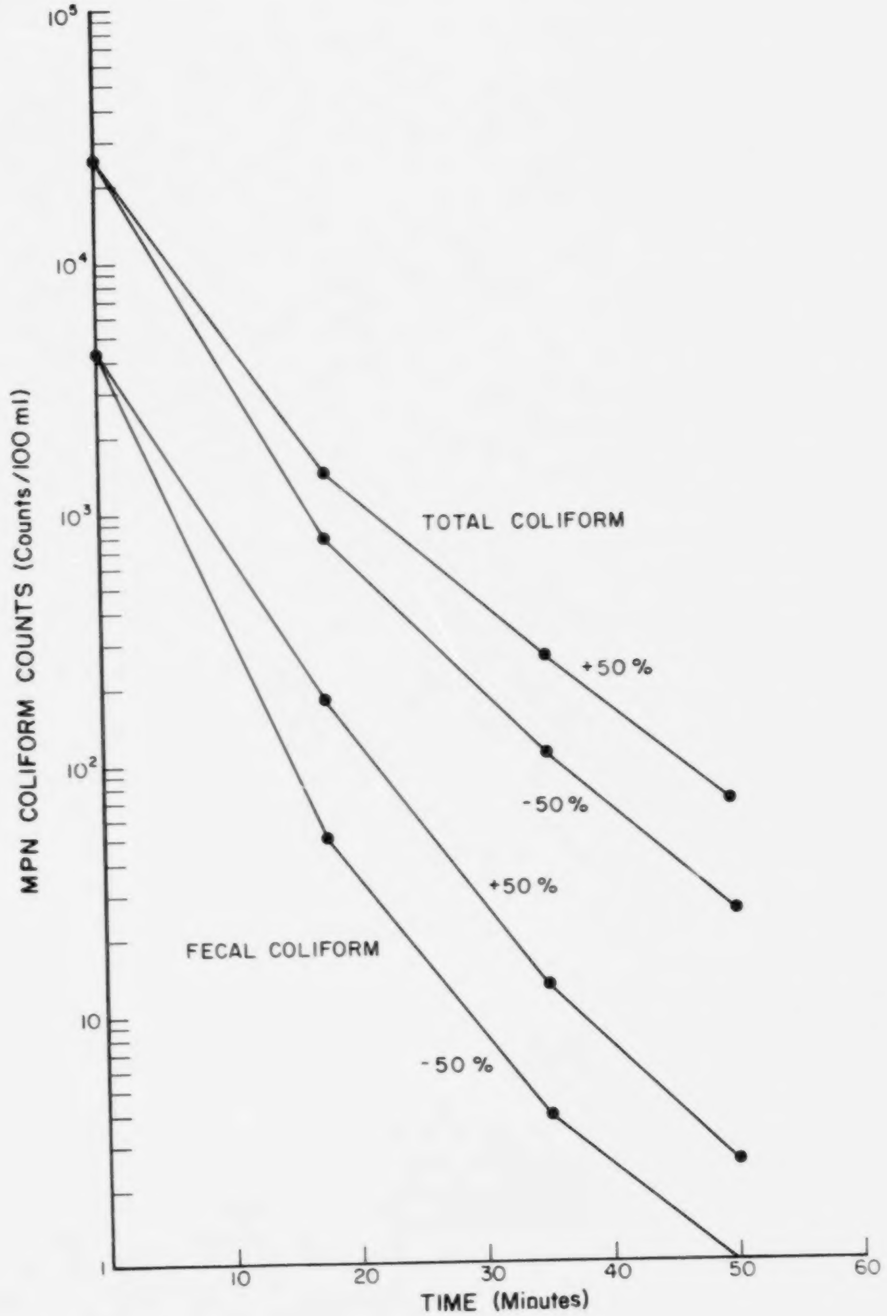


Figure 90. Variation of coliform MPN with fluctuations of CC5 by ± 50 percent.

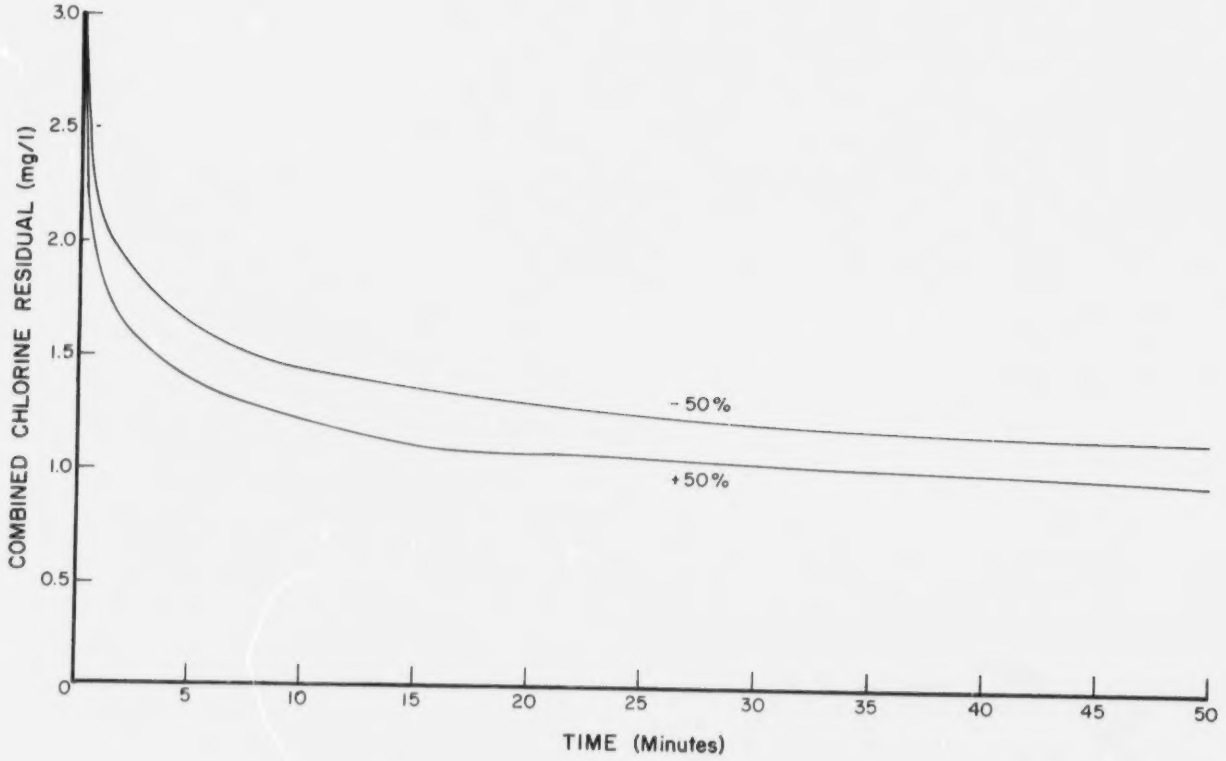


Figure 91. Variation of chlorine residual with fluctuations of CC5 by ± 50 percent.

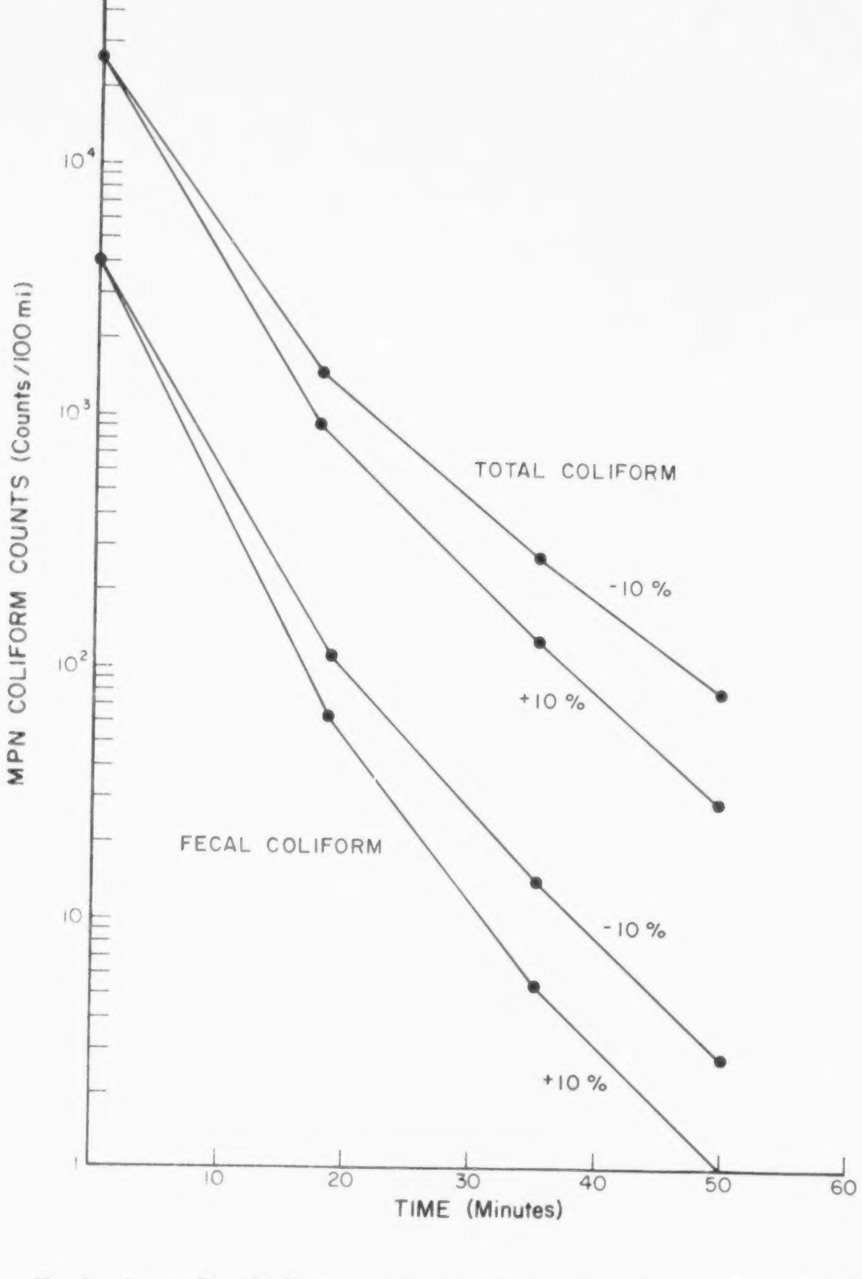


Figure 92. Variation of coliform, with fluctuations of CHOCLT and CNH2CL by ± 10 percent.

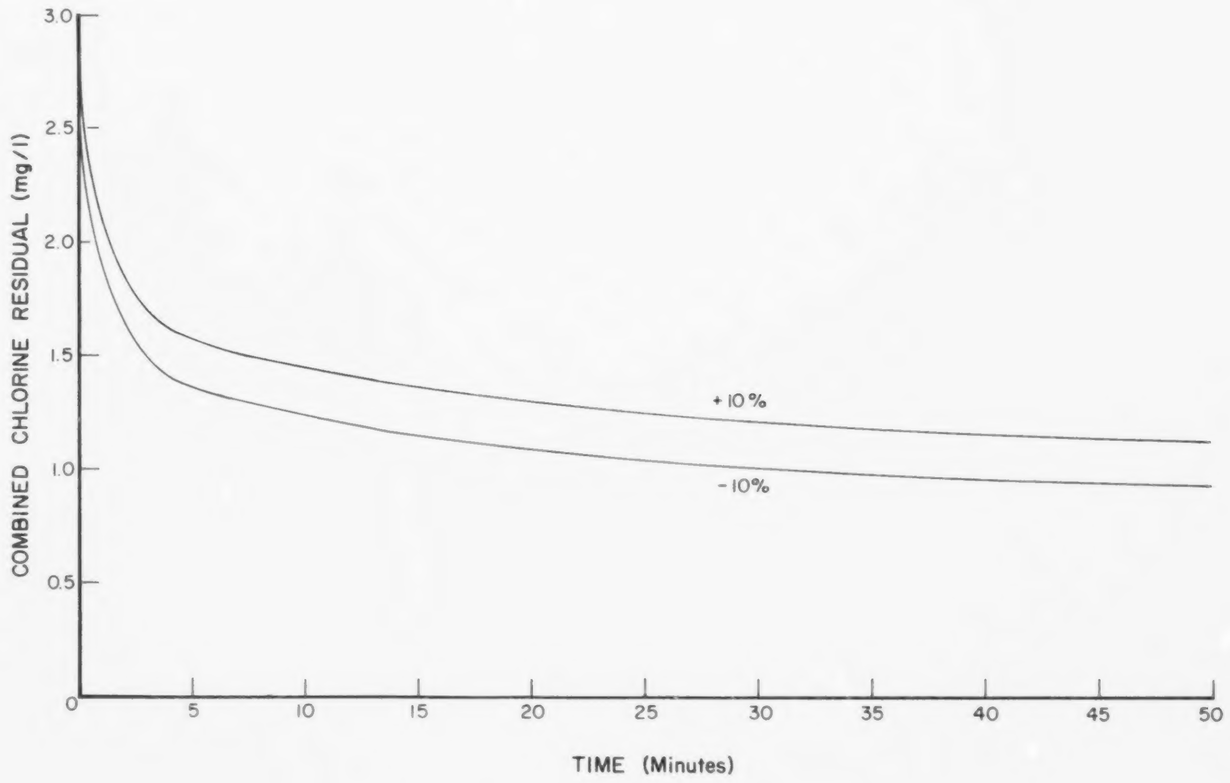


Figure 93. Variation of chlorine residual with fluctuations of CHOCLT and CNH2CL by ± 10 percent.

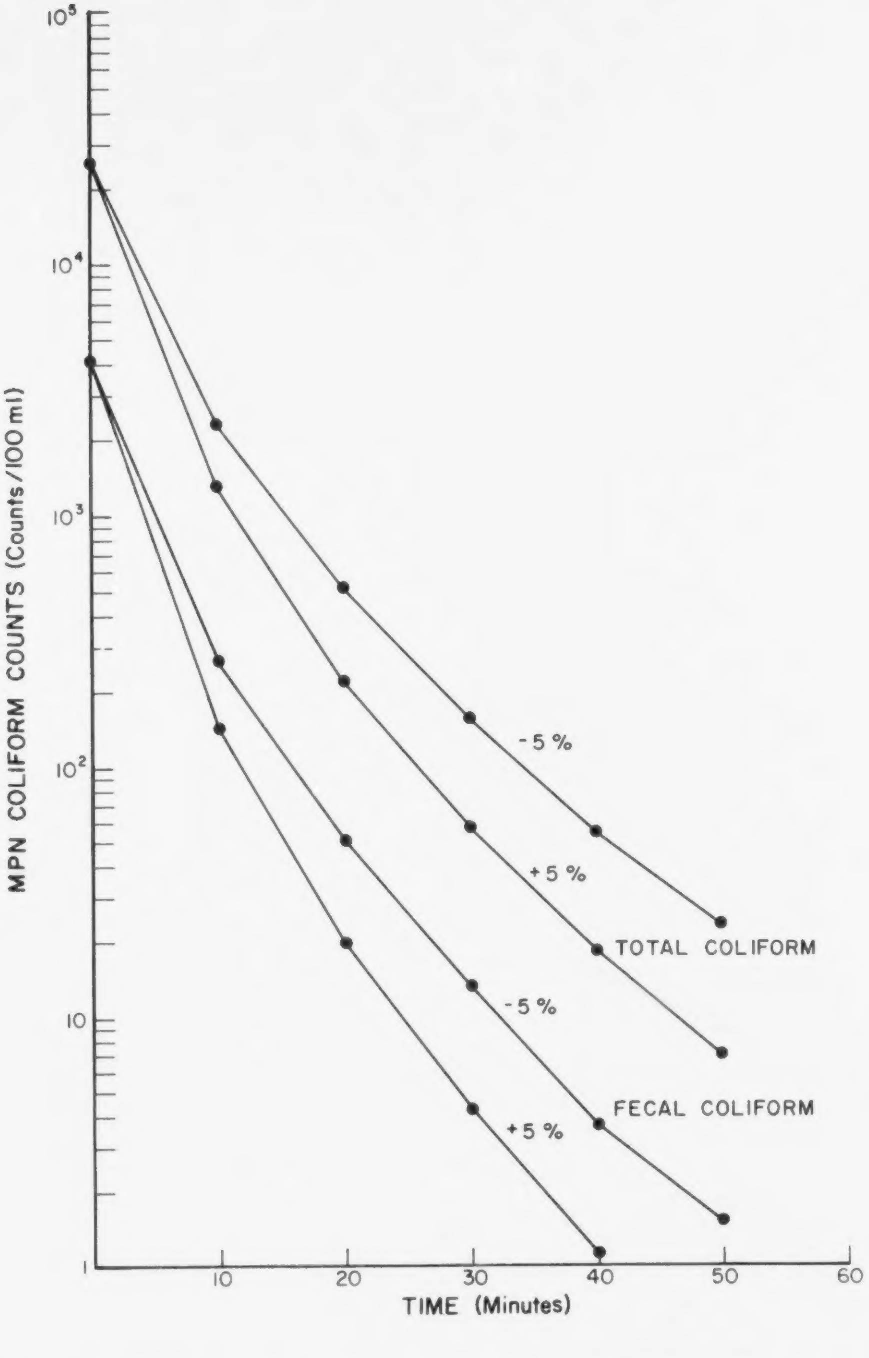


Figure 94. Variations of coliform with fluctuations of TADJ by ± 5 percent at $22^{o}C$.

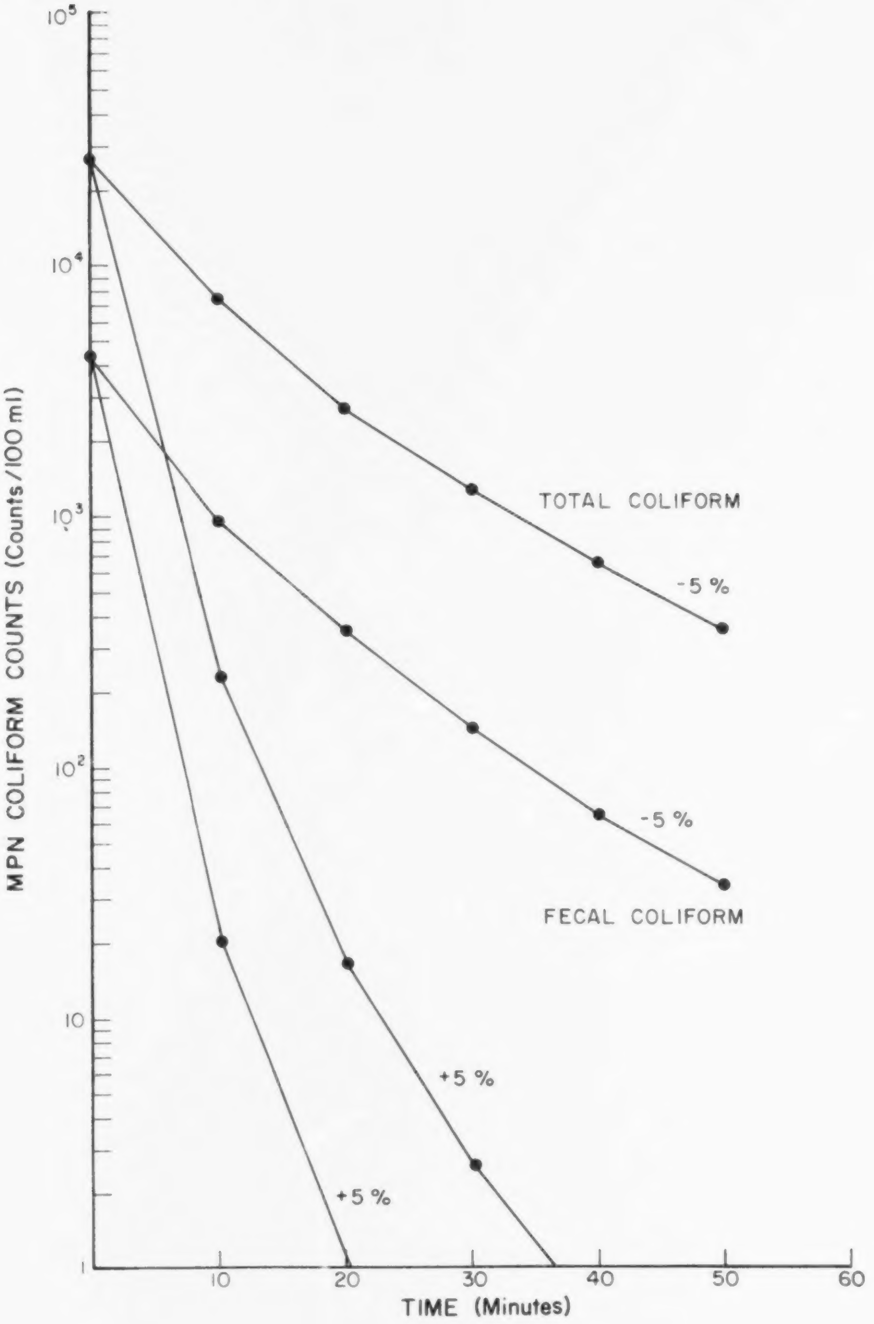


Figure 95. Variation of coliform with fluctuations of TADJ by ± 5 percent at 5°C.

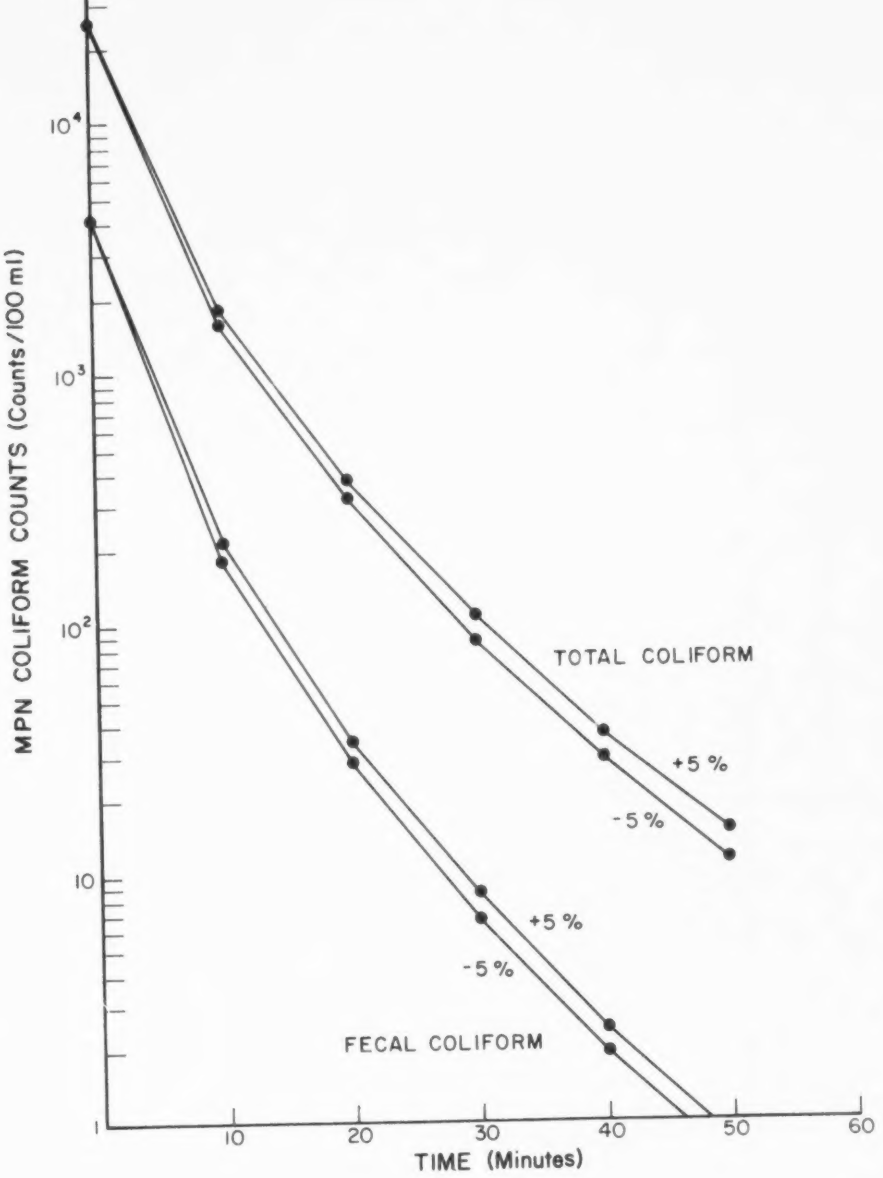


Figure 96. Variation of coliform with fluctuations of TADJ2 by ± 5 percent at $22^{o}C$.

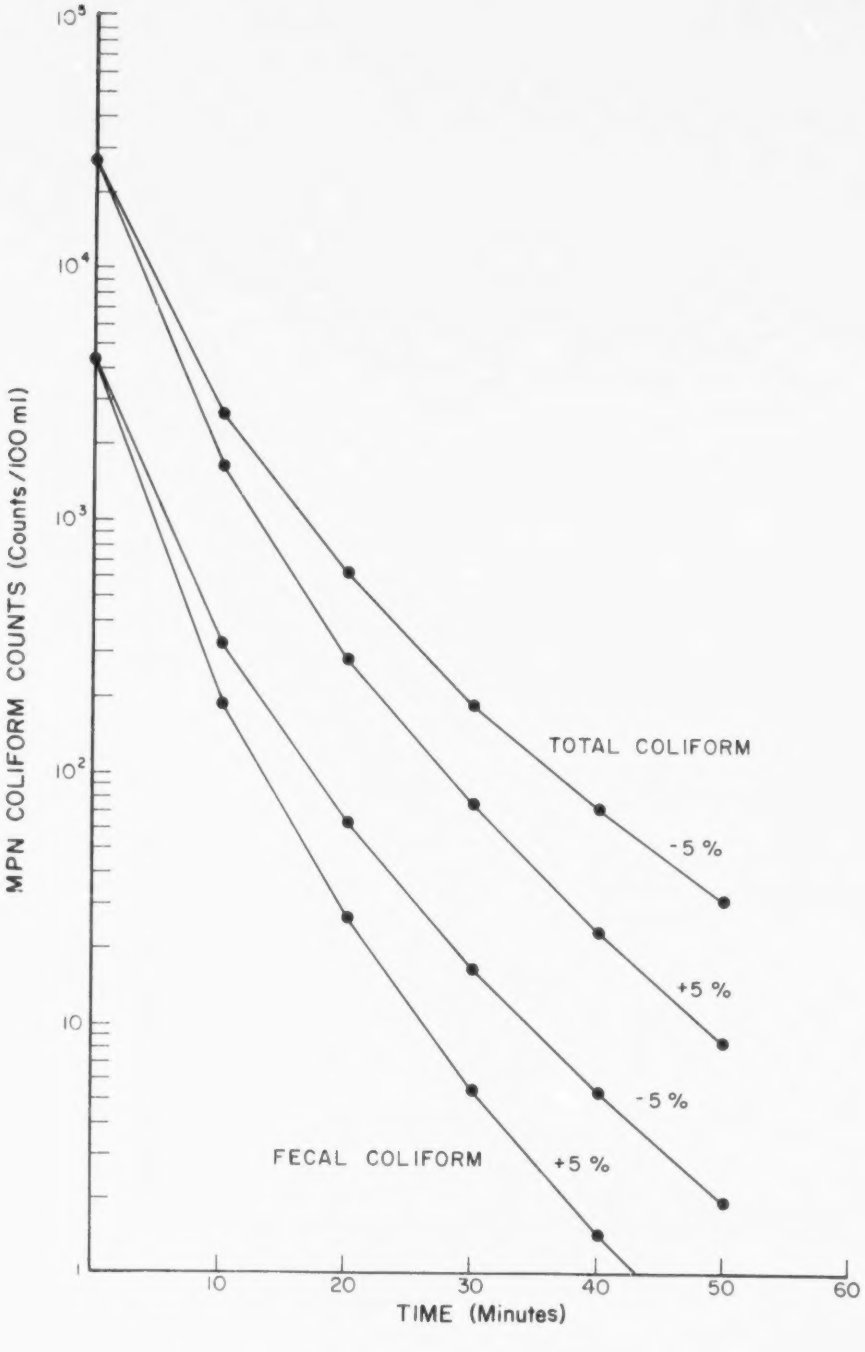


Figure 97. Variation of coliform with fluctuations of TADJ2 by ± 5 percent at $5^{o}C$.

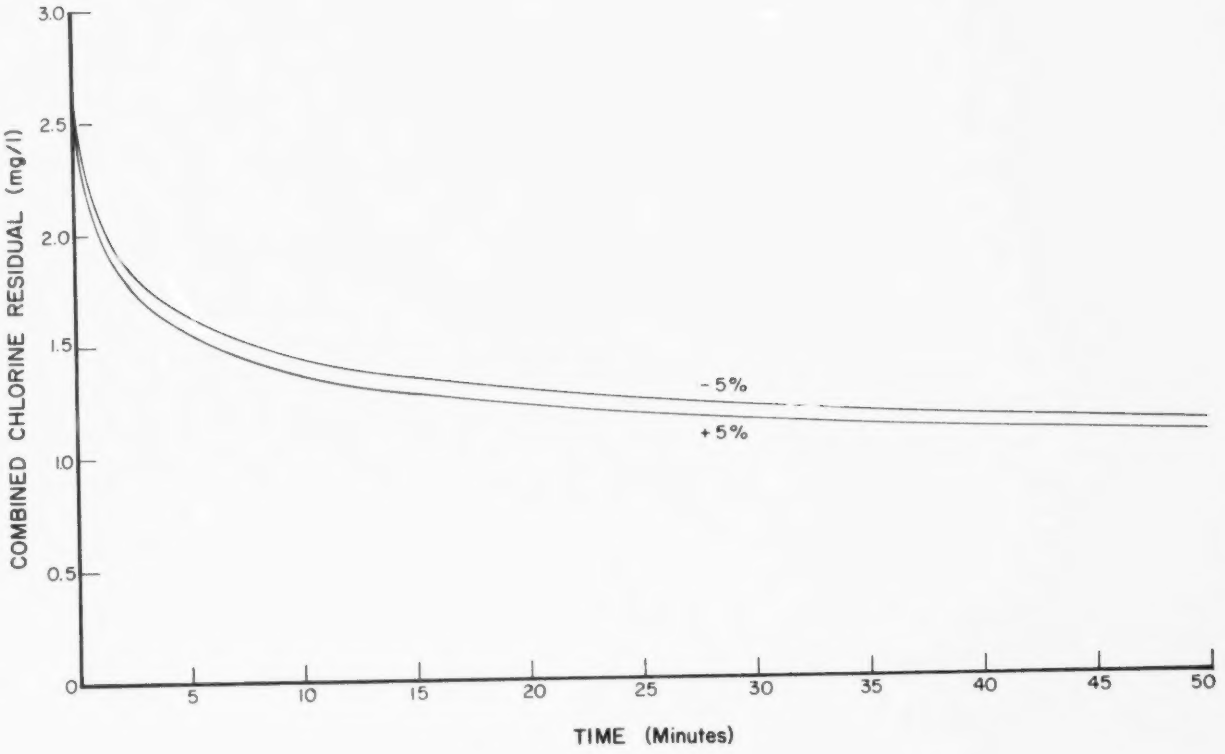


Figure 98. Variation of chlorine residual with fluctuations of TADJ2 by ± 5 percent at 22°C.

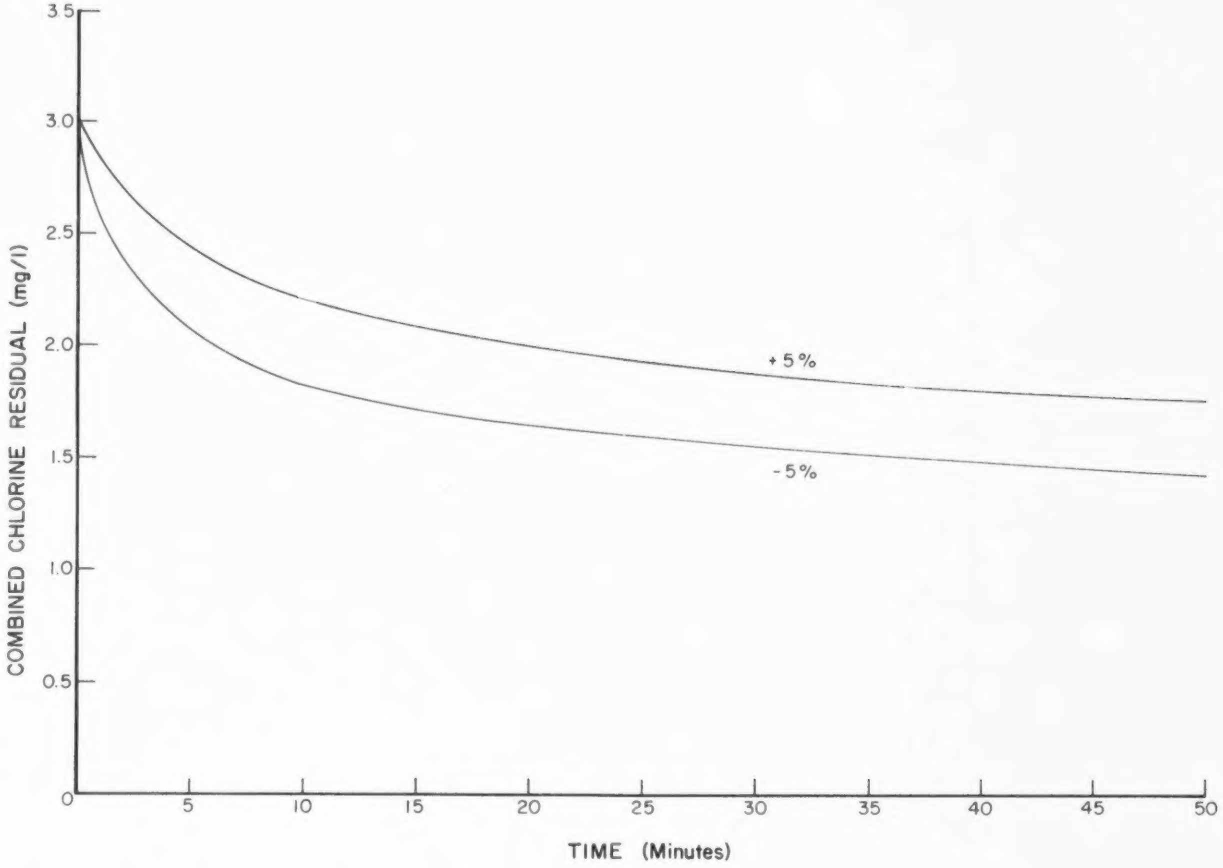


Figure 99. Variation of chlorine residual with fluctuations of TADJ2 by ± 5 percent at 5°C.

Results of the sensitivity analysis indicate that at colder temperatures, TADJ is the most sensitive parameter in affecting the reduction of total and fecal coliforms. At warmer temperatures of around 20°C, CTOTAL and CFECAL are the most sensitive parameters in determining bacterial reduction. Of the parameters evaluated, CC5 was found to be the least sensitive. For fluctuations in chlorine residual, TADJ2 was found to be the most sensitive parameter at colder temperatures while CHOCLT and CNH2CL were found to be the most sensitive at about 20°C. For those parameters affecting chlorine residual, CC5 was found to be the least sensitive.

MODEL VERIFICATION

A determination of the ability of CHLOR-I to predict reasonable results was made by comparing the model results for a given set of initial conditions with each set of field data for the entire study period. This was done by calculating the correlation coefficient, R, between each set of predicted and observed values for free and combined chlorine and for total and fecal coliform. SS reductions were observed, but correlation coefficients were not calculated between predicted and observed values because of the variability of the settling fraction, F. NH_3-N and SCOD changes were also observed, but because of the small amount of data involved in breakpoint chlorination, changes in these chemical parameters were of limited importance in verifying the model.

When free chlorine was produced, the R between predicted and observed data was found to be greater than 0.96, indicating correlation at the 99 percent confidence level. This high level of correlation is heavily influenced by the initial conditions, where the observed and predicted values are equal, and these values are large in comparison with the results after several minutes of contact. However, the model does appear to adequately describe the chlorination of lagoon effluents well within the limits of the precision of most field and laboratory analyses, particularly when consideration is given for the multitude of immeasurable variables.

In comparing the degree of fit between predicted and observed combined chlorine residual, it was found that 60 percent of all data sets produced a correlation coefficient, R, of 0.86 or better. This represents a confidence level of 95 percent. The predicted values compared poorly with observed data for cases in which breakpoint chlorination was involved. This is largely due to the high variability in the organic nitrogen correction factor, CORNH3. When the data involving breakpoint chlorination were eliminated from consideration, 65 percent of the data sets produced values of R within the 95 percent confidence level.

For coliform reduction, it was found that for both total and fecal coliform, 81 percent of the data sets produced an R of 0.87 or greater. This corresponds to a confidence level of 95 percent. An R of 0.96 or better was achieved for 72 percent of the data sets, representing the 99 percent confidence level.

The model, CHLOR-I, was used to construct a series of design curves for selecting the optimal chlorine dose necessary to achieve a desired level of disinfection. CHLOR-II was not used in the preparation of these curves for reasons previously discussed. Assuming that the data collected from this study are typical for waste stabilization lagoons, it should rarely, if ever, be necessary to use breakpoint chlorination to achieve satisfactory disinfection. Therefore, the design curves are based upon disinfection using combined chlorine residual only. If cases arise where it may be necessary to use free chlorine to achieve a desired level of disinfection, the model can be applied directly to obtain estimates of the chlorine dose required.

The design curves presented in Figures 100 through 114 show the levels of total and fecal coliform reduction expected for various combinations of combined chlorine residual and time. Each design curve represents a different combination of initial coliform concentrations and temperature. Total and fecal coliform ranges may vary between 10^2-10^6 MPN counts/100 ml. Temperatures vary between 5-25°C. The percentage of bacterial kill within a certain contact period is indicated by log (N_o/N), where N_o is the initial bacterial concentration and N is the bacterial concentration at time t. For example, if log (N_o/N) is equal to 2.0, it indicates a 99 percent removal of bacteria. Each chart includes removal up to 99.999 percent.

After determining the concentration of combined chlorine residual necessary to achieve a certain level of bacterial reduction within a specified contact period, it is necessary to determine the chlorine dose required to produce that residual. Since the residual obtained for a specific chlorine dose is primarily determined by temperature, sulfide, and TCOD, a series of curves have been prepared to determine the dose required to produce the desired residual under varying conditions. Rather than referring to a large number of design curves for covering a wide range of possible combinations of these key parameters, the determination of chlorine dose has been reduced to several curves expressed in terms of equivalent chlorine residual.

Once the chlorine residual necessary to produce adequate disinfection at any particular temperature is known, it is converted to the equivalent chlorine residual that would result from the same chlorine dose if the temperature was 20°C. This conversion is made by use of Figure 115. If sulfide is initially present in the wastewater, this figure is bypassed and it is necessary to go directly to Figure 116.

Sulfide production in stabilization lagoons is generally limited to times of the year when the lagoons freeze over and anaerobic conditions prevail. These conditions are accompanied by colder water temperatures. Therefore, it is assumed that most sulfide production will occur around 5°C or less. At 5°C it is not necessary to compensate for temperature in using Figure 117. This graph is used to convert the residual necessary at 5°C and any TCOD to the equivalent chlorine residual which would be produced from the same chlorine dose if the TCOD were 60 mg/l. It is now possible to select one of Figures 117-120 to determine the chlorine dose required to produce the desired equivalent chlorine residual for a given initial sulfide concentration between 0.5 and 2.0 mg/l. The amount of sulfide reduction for a given combination of chlorine dose and initial sulfide is determined from Figure 121.

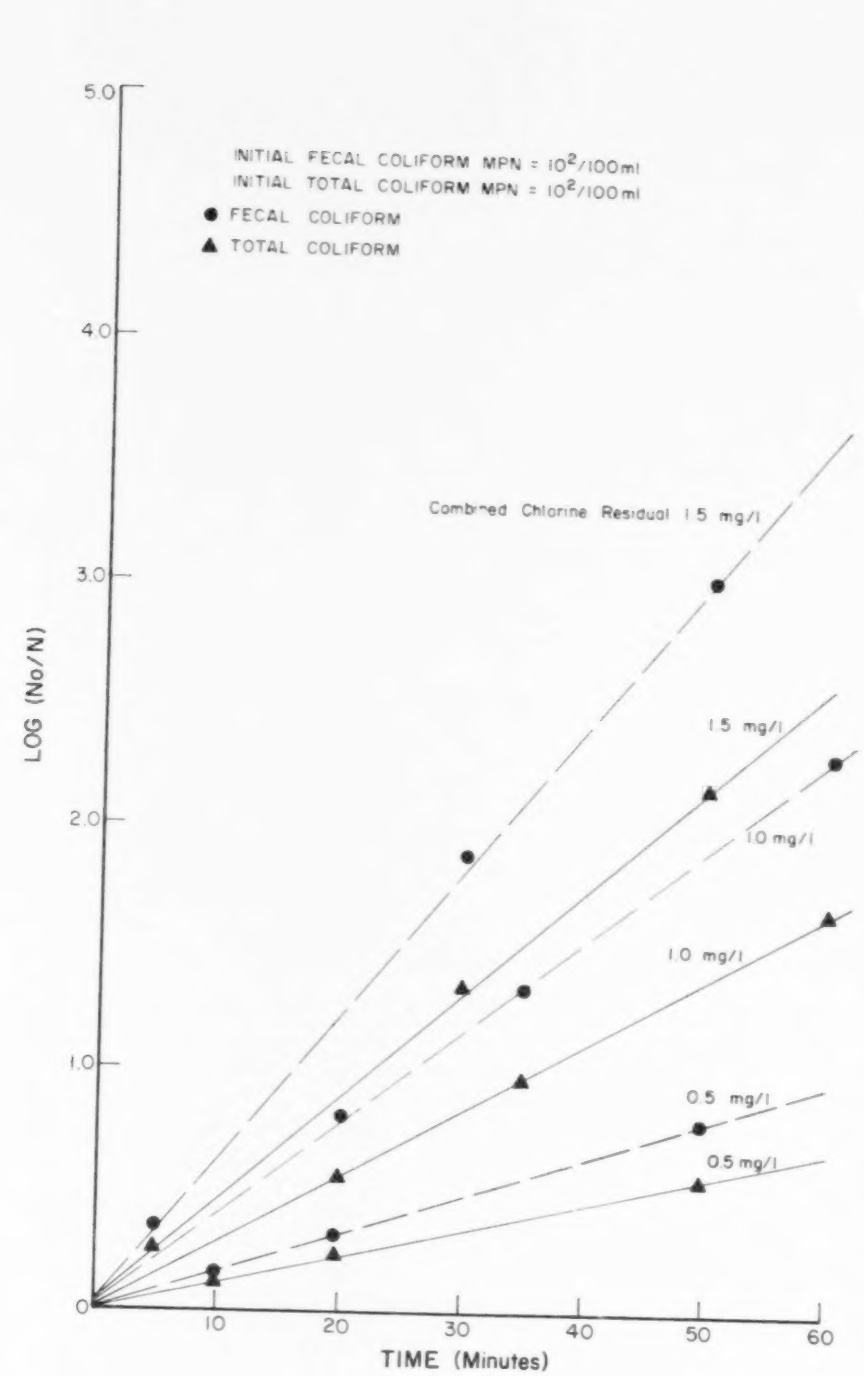


Figure 100. Combined chlorine residual at 5^oC for coliform MPN = 10^2.

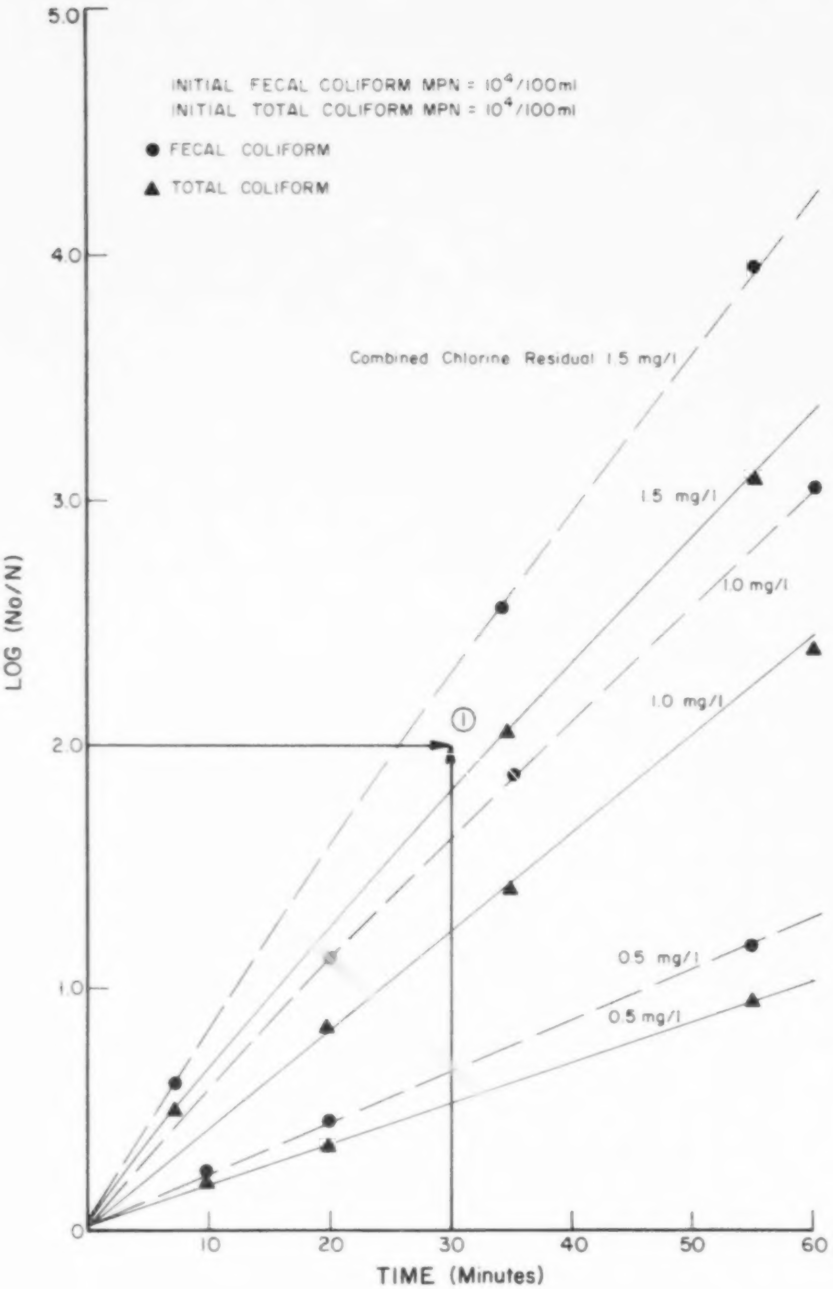


Figure 101. Combined chlorine residual at 5°C for coliform MPN = 10^4/100 ml.

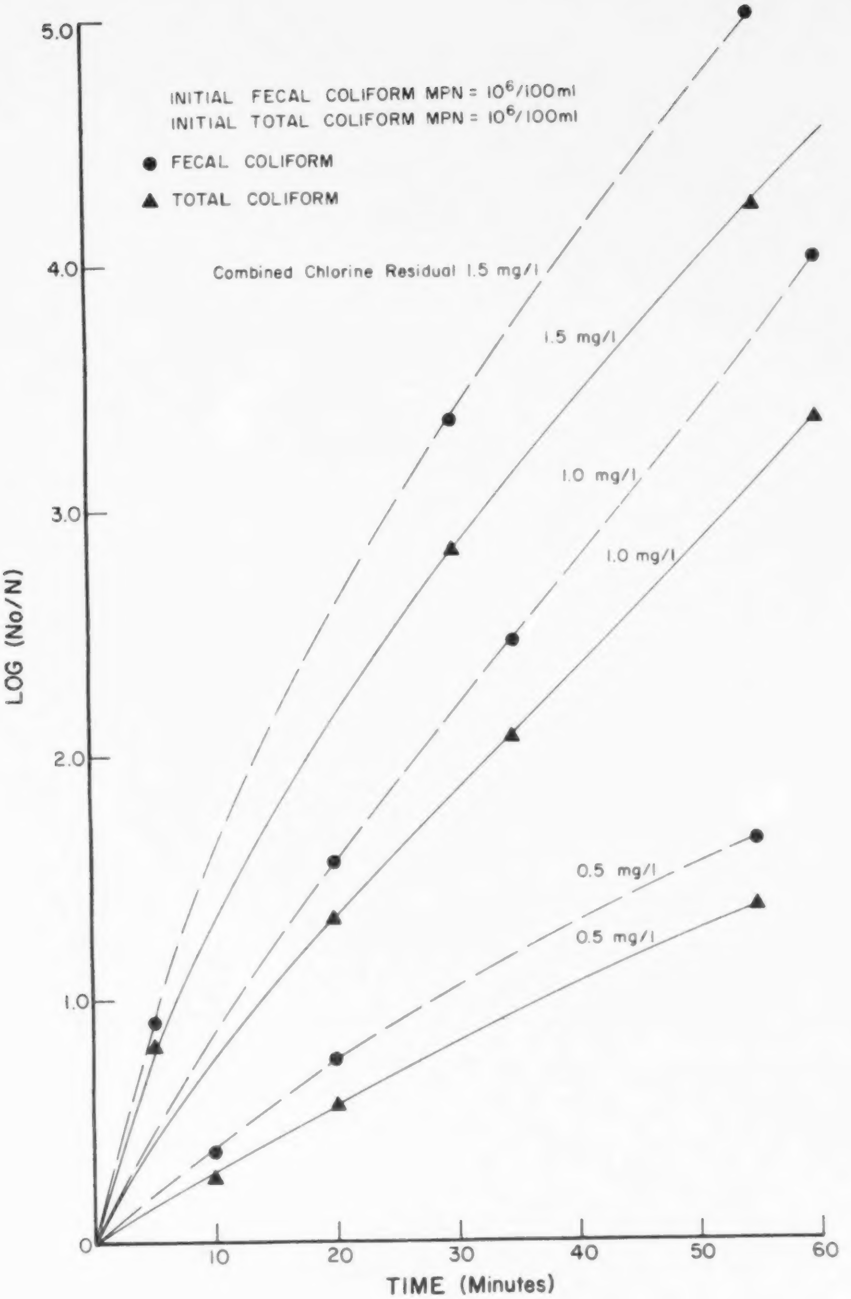


Figure 102. Combined chlorine residual at 5°C for coliform MPN = 10^6.

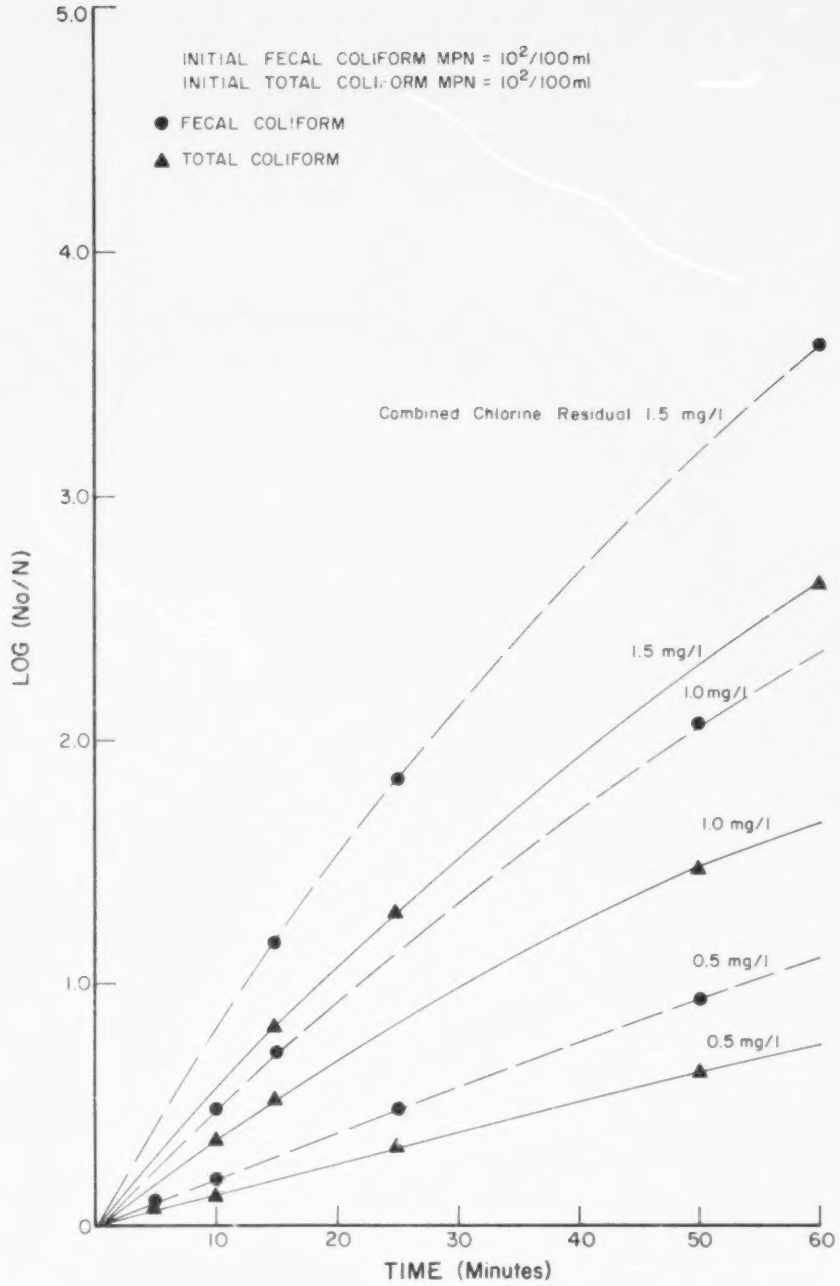


Figure 103. Combined chlorine residual at 10°C for coliform MPN = 10^2.

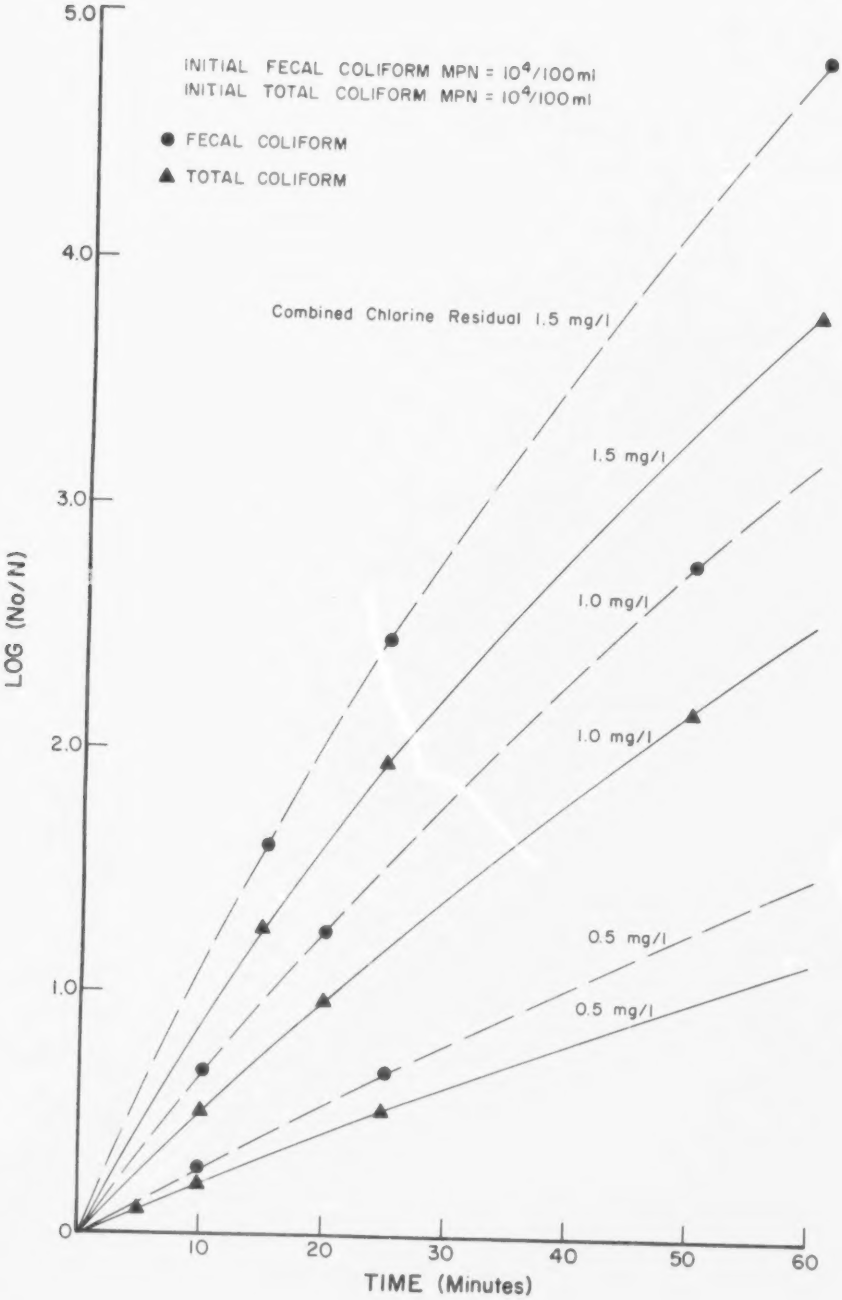


Figure 104. Combined chlorine residual at 10°C for coliform MPN = 10^4.

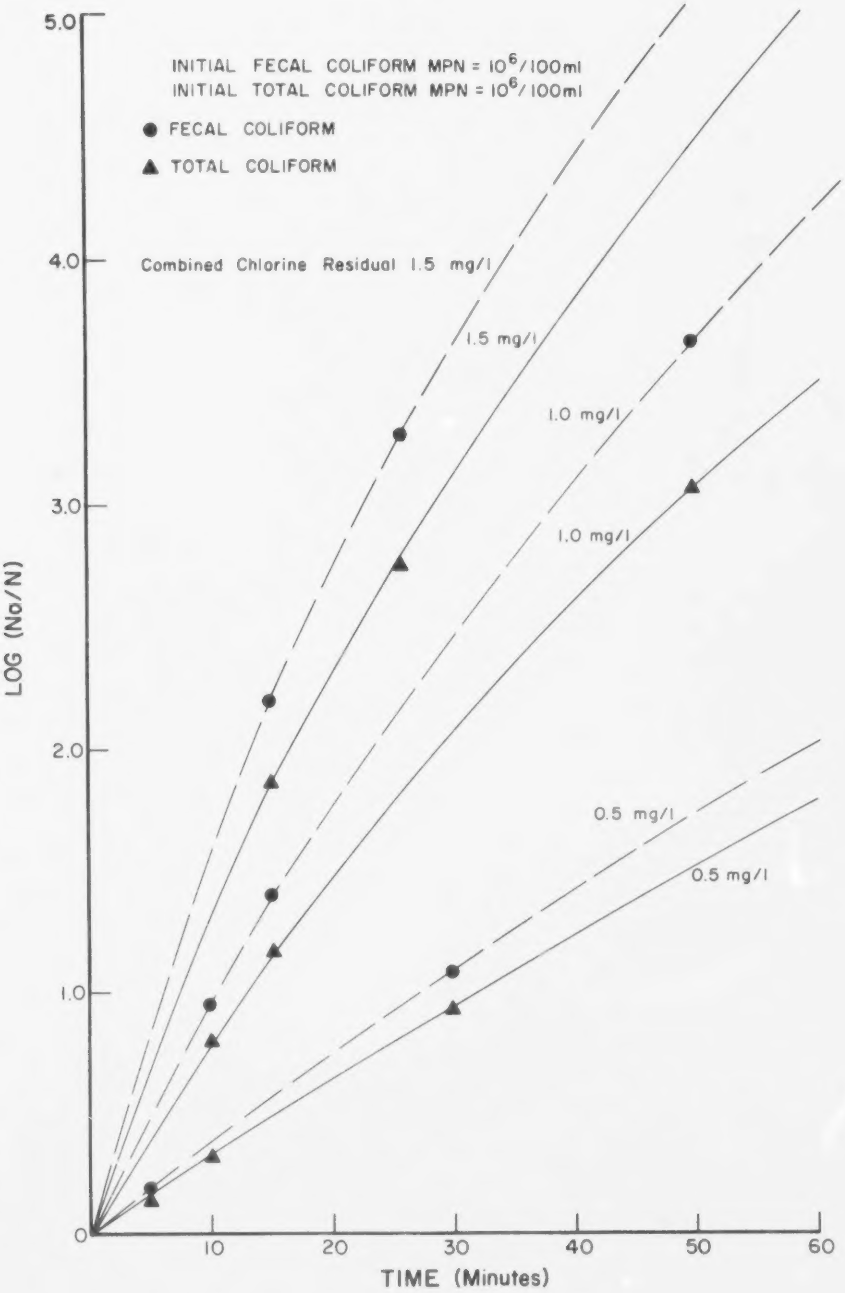


Figure 105. Combined chlorine residual at 10^oC for coliform MPN = 10^6.

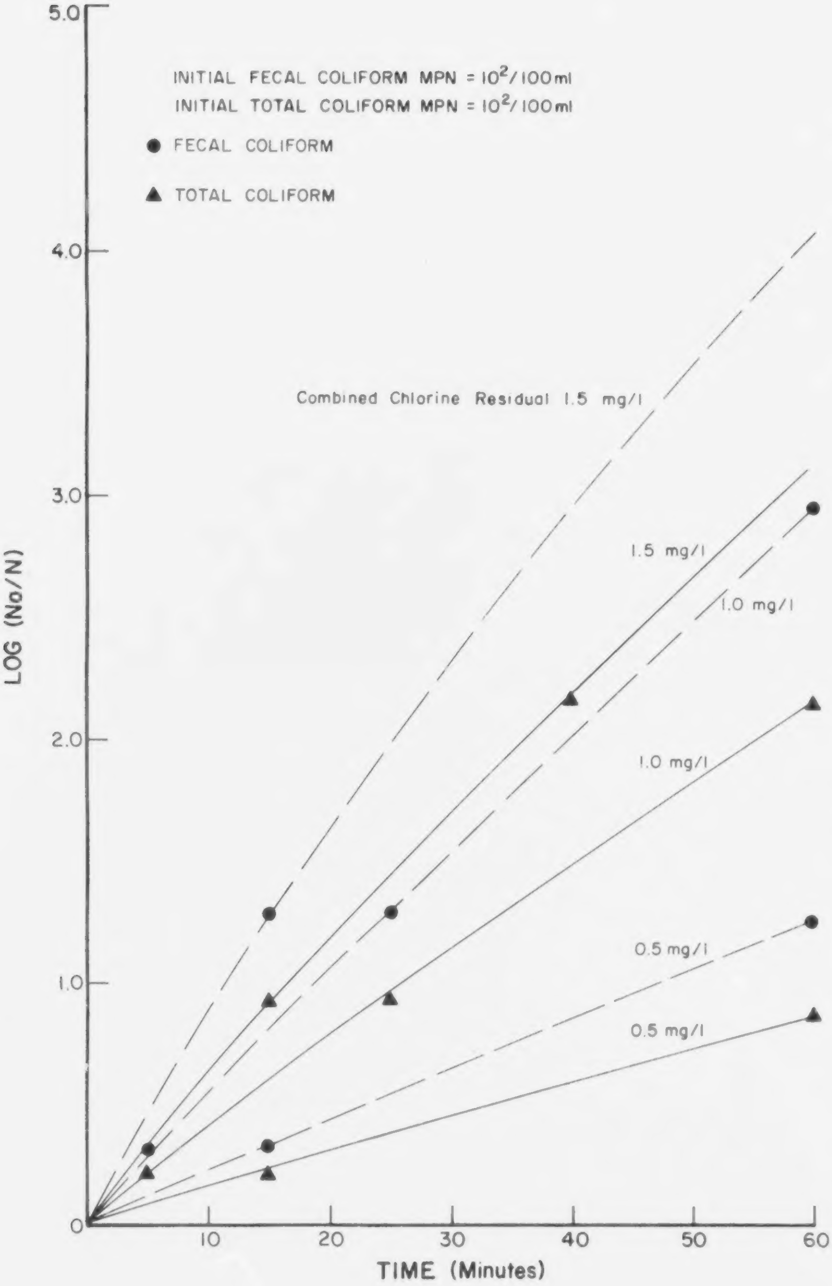


Figure 106. Combined chlorine residual at 15°C for coliform MPN = 10^2.

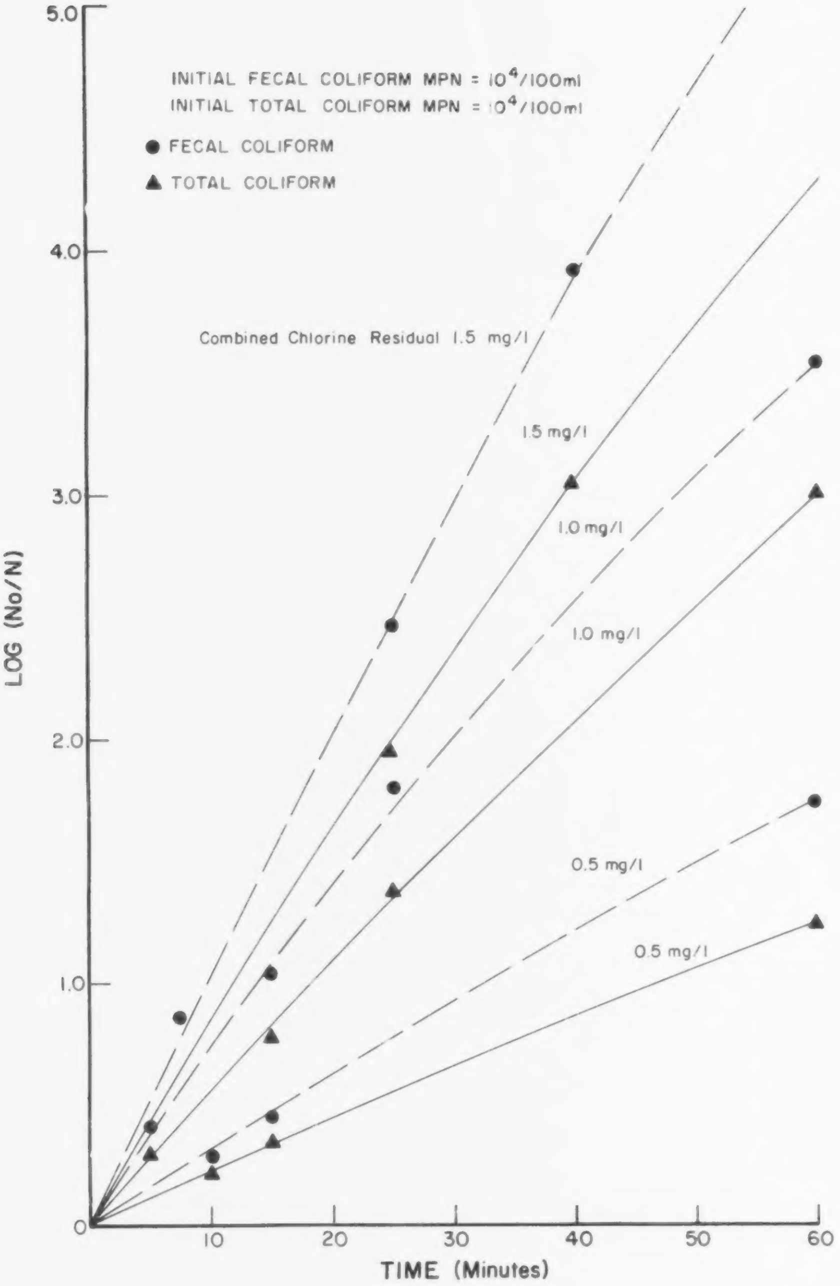


Figure 107. Combined chlorine residual at 15^{o}C for coliform MPN = 10^4.

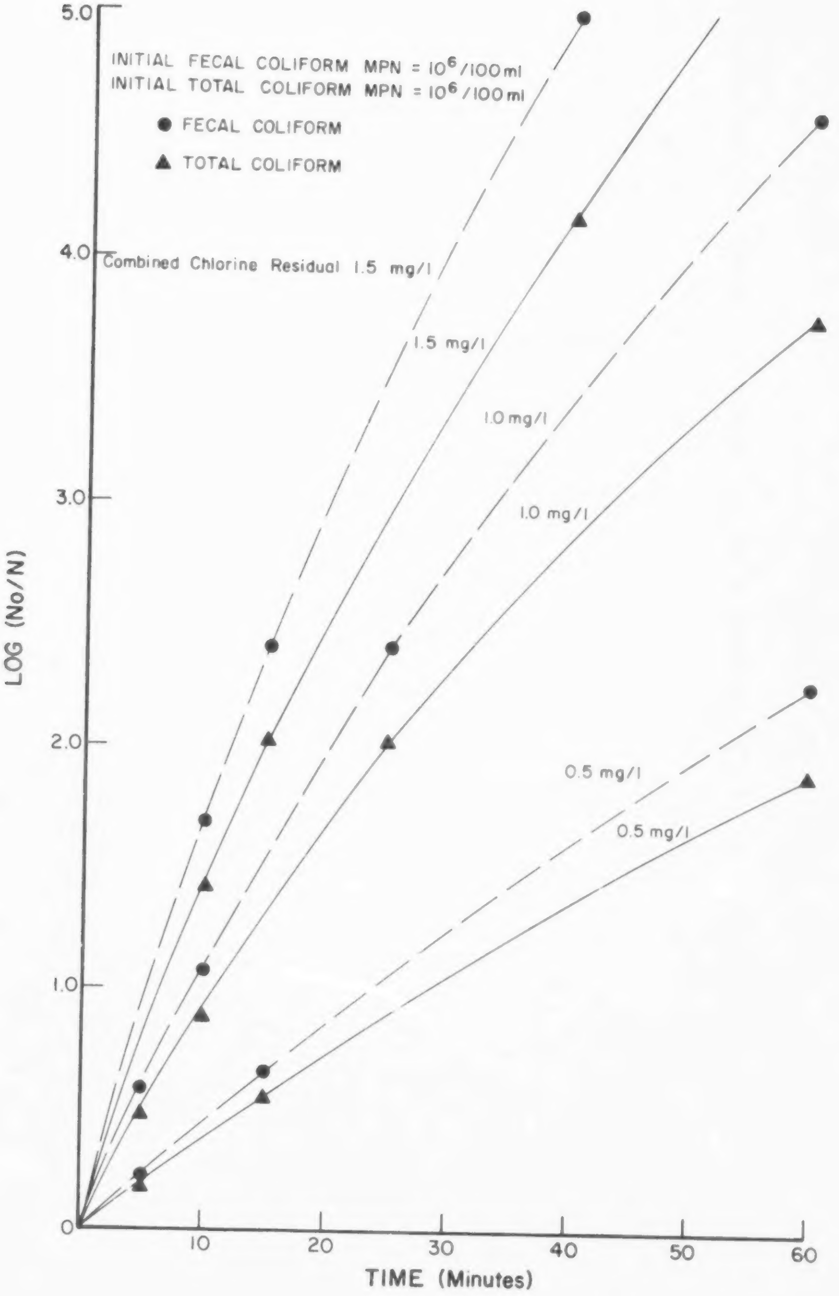


Figure 108. Combined chlorine residual at 15°C for coliform MPN = 10^6.

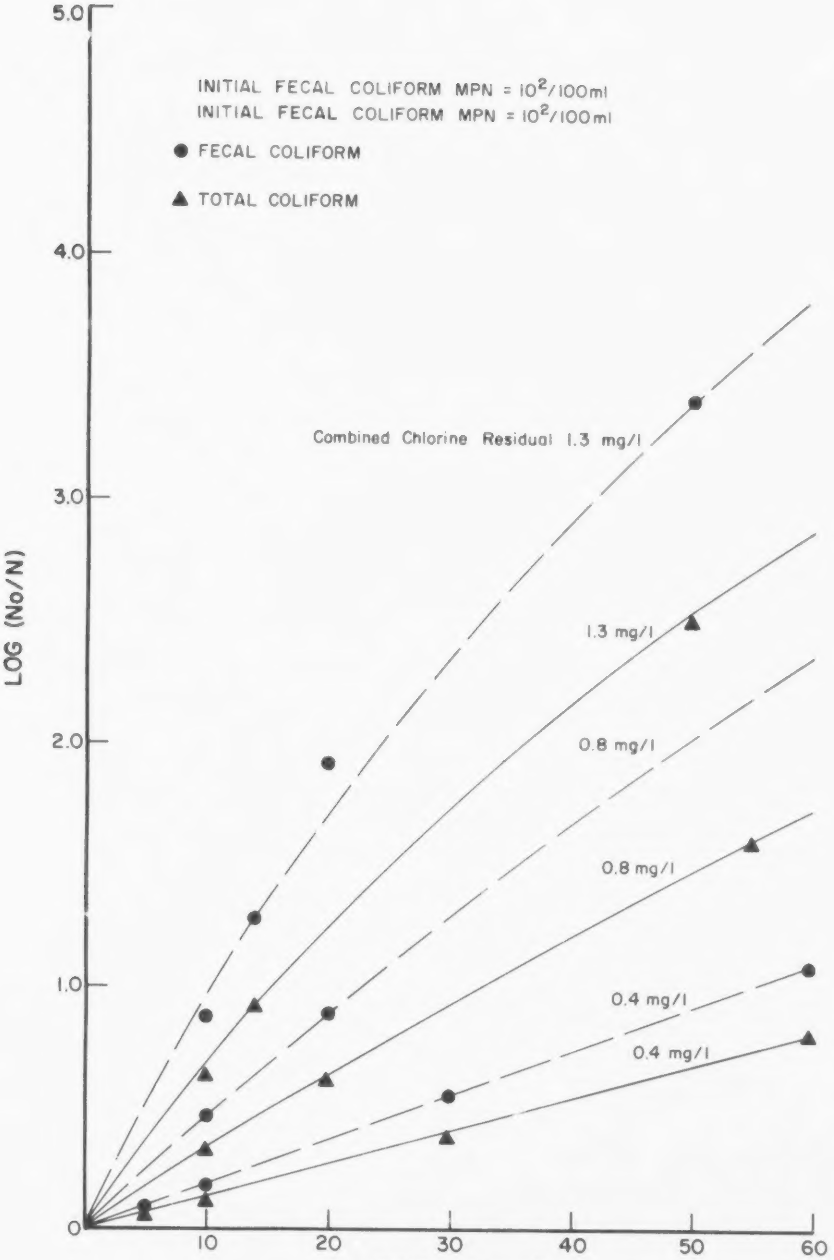


Figure 109. Combined chlorine residual at 20°C for coliform MPN = 10^2.

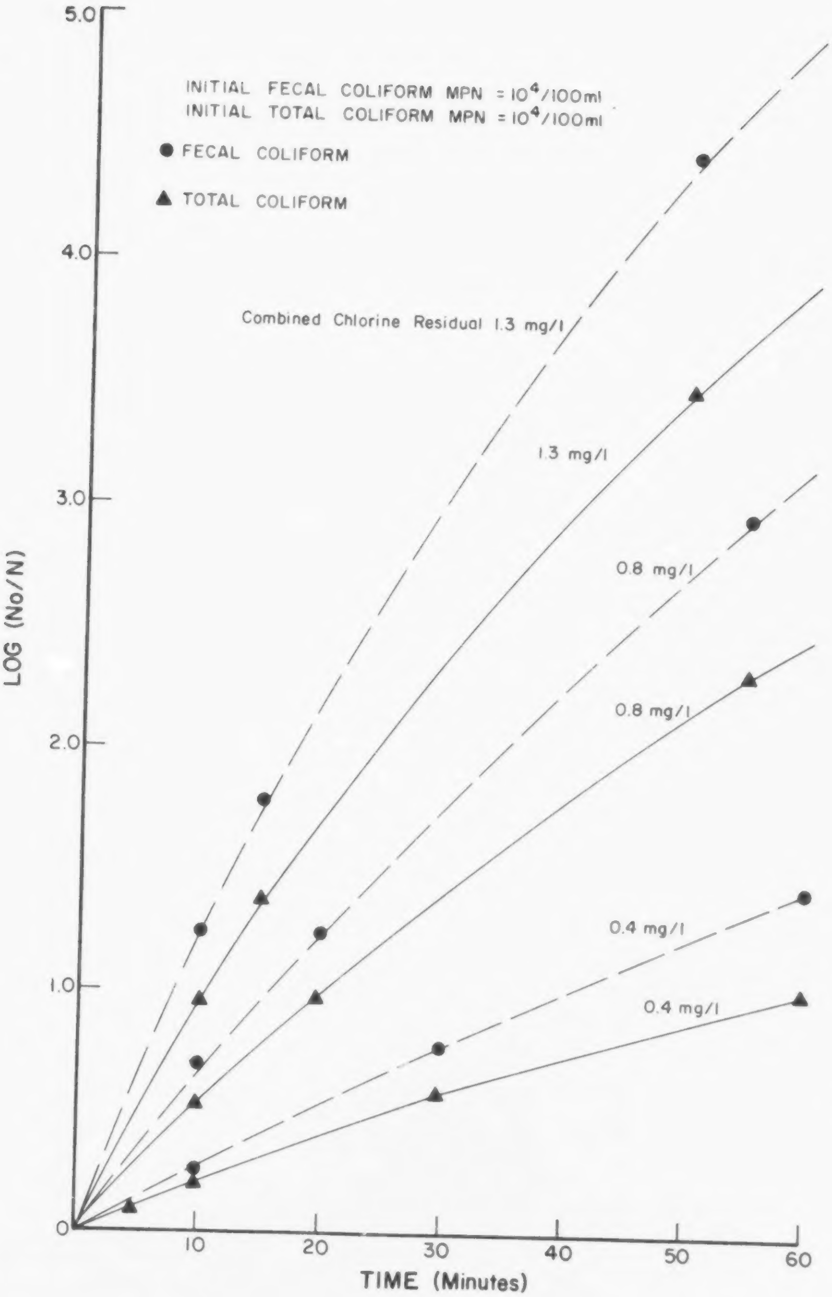


Figure 110. Combined chlorine residual at 20°C for coliform MPN = 10^4.

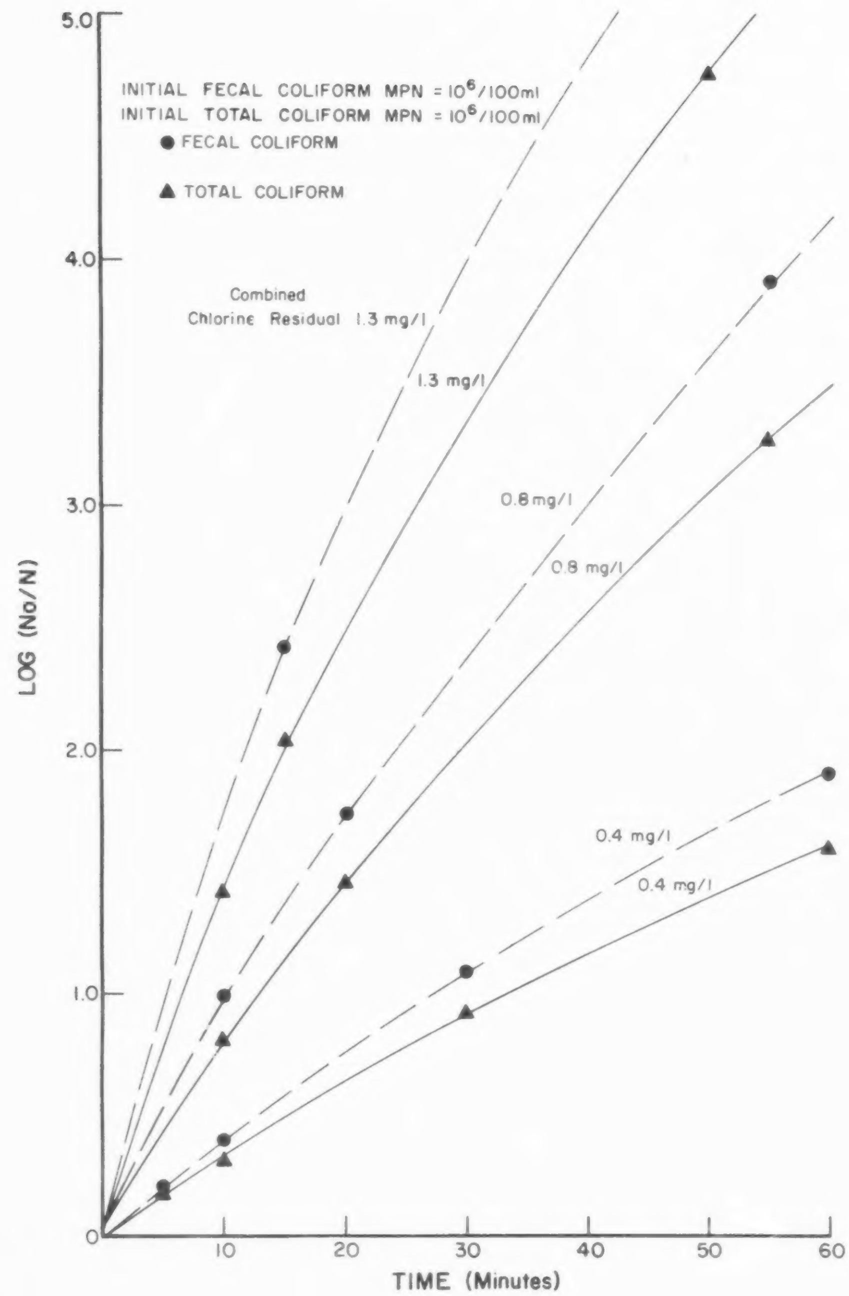


Figure 111. Combined chlorine residual at 20°C for coliform MPN = 10^6.

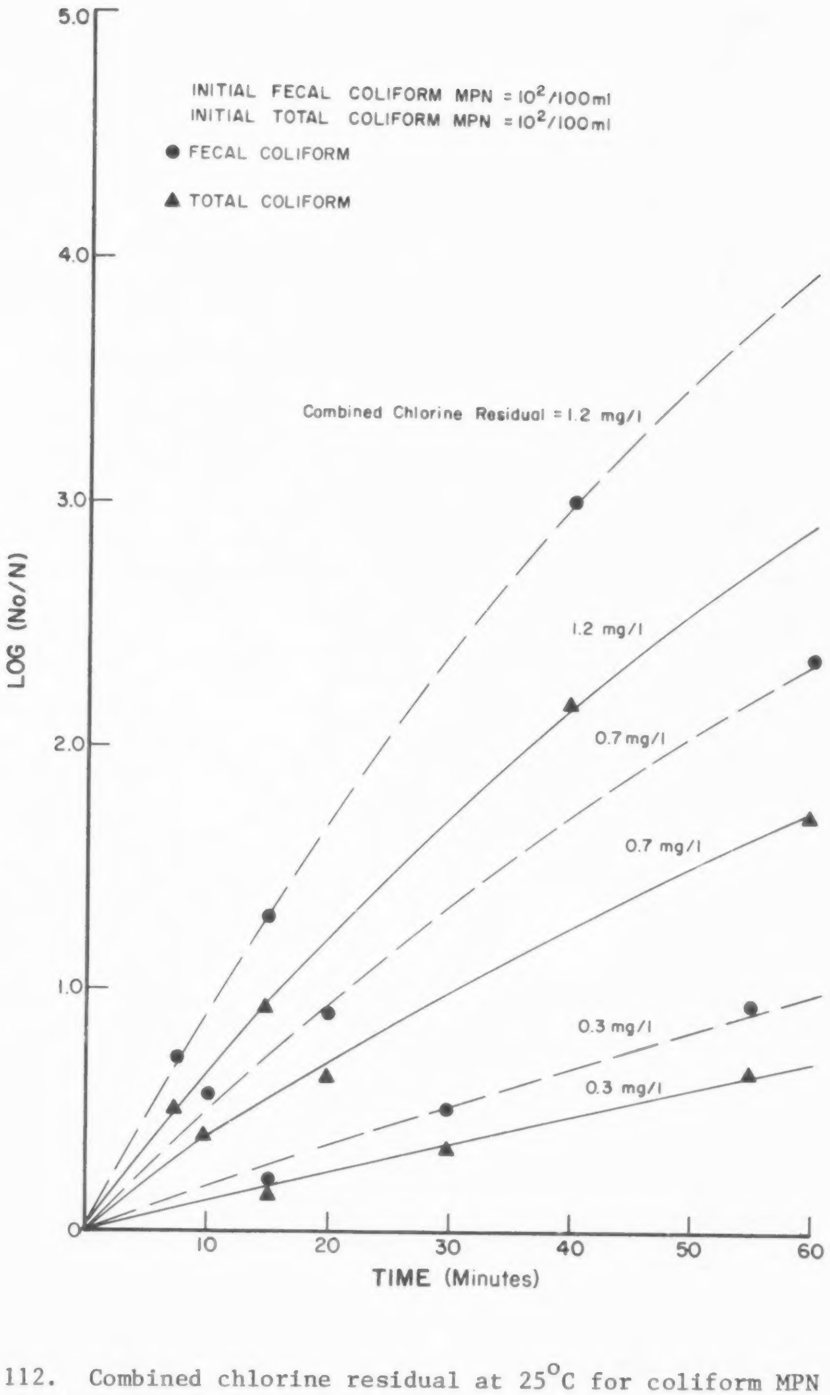


Figure 112. Combined chlorine residual at 25°C for coliform MPN = 10^2.

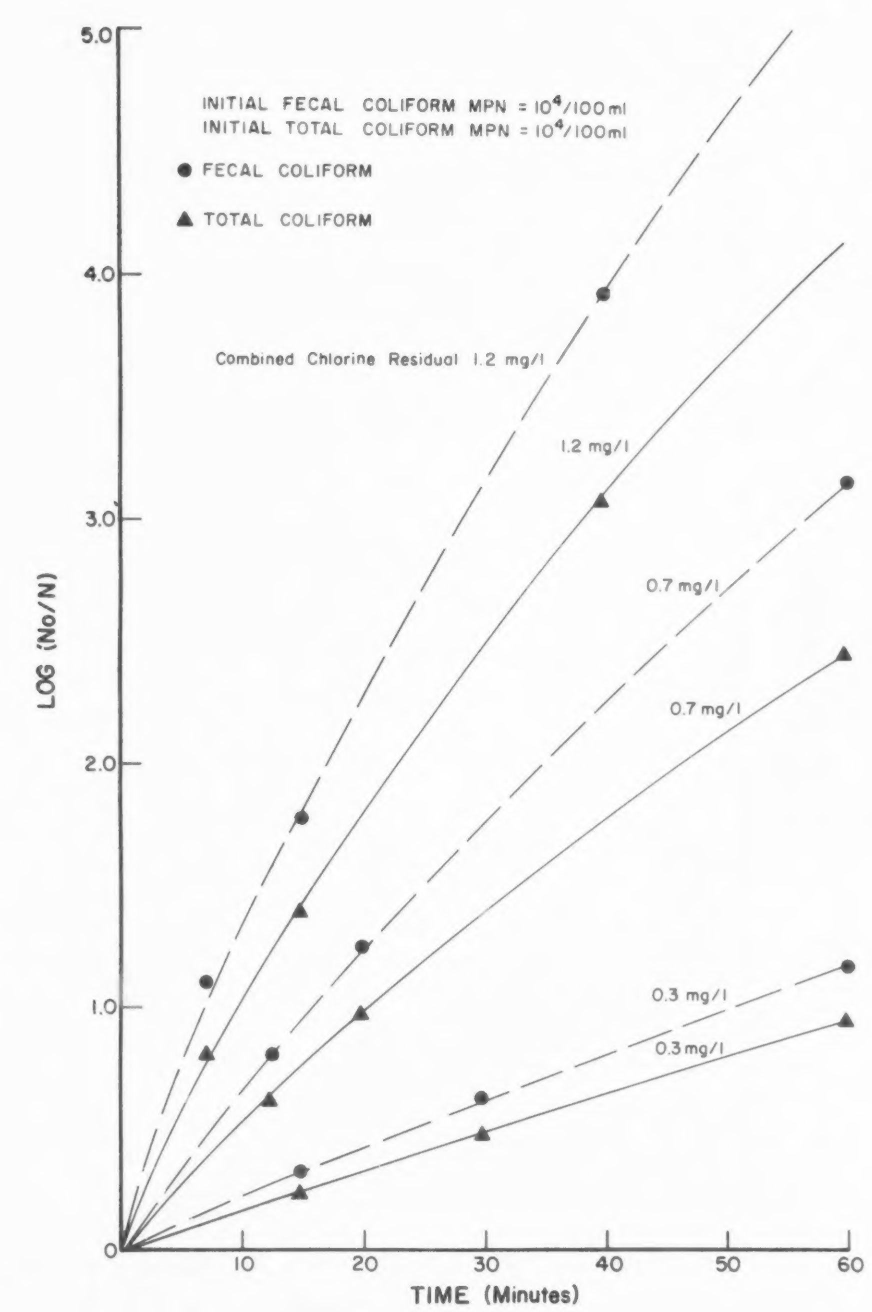


Figure 113. Combined chlorine residual at 25°C for coliform MPN = 10^4.

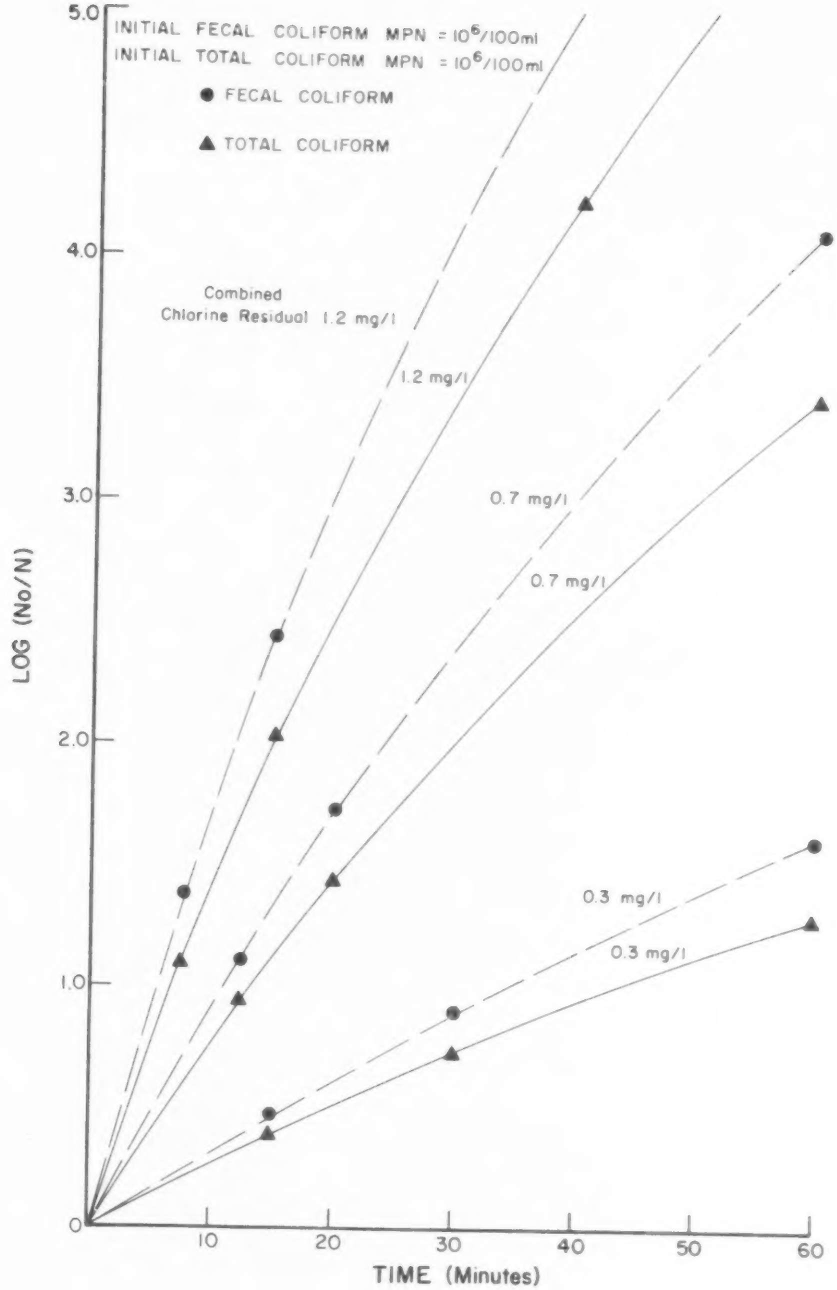


Figure 114. Combined chlorine residual at 25°C for coliform MPN = 10^6.

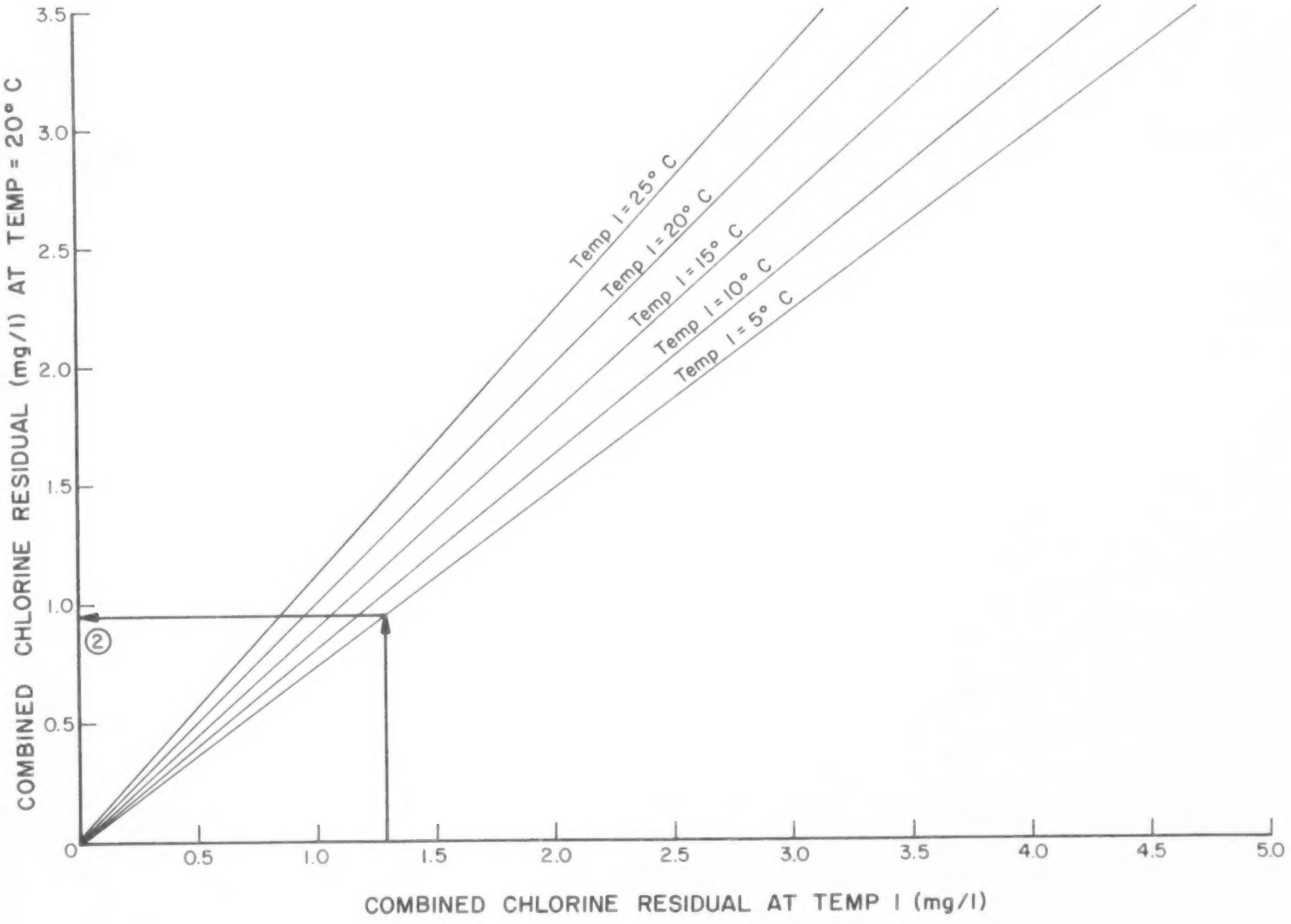


Figure 115. Conversion of combined chlorine residual at Temp 1 to equivalent residual at 20°C.

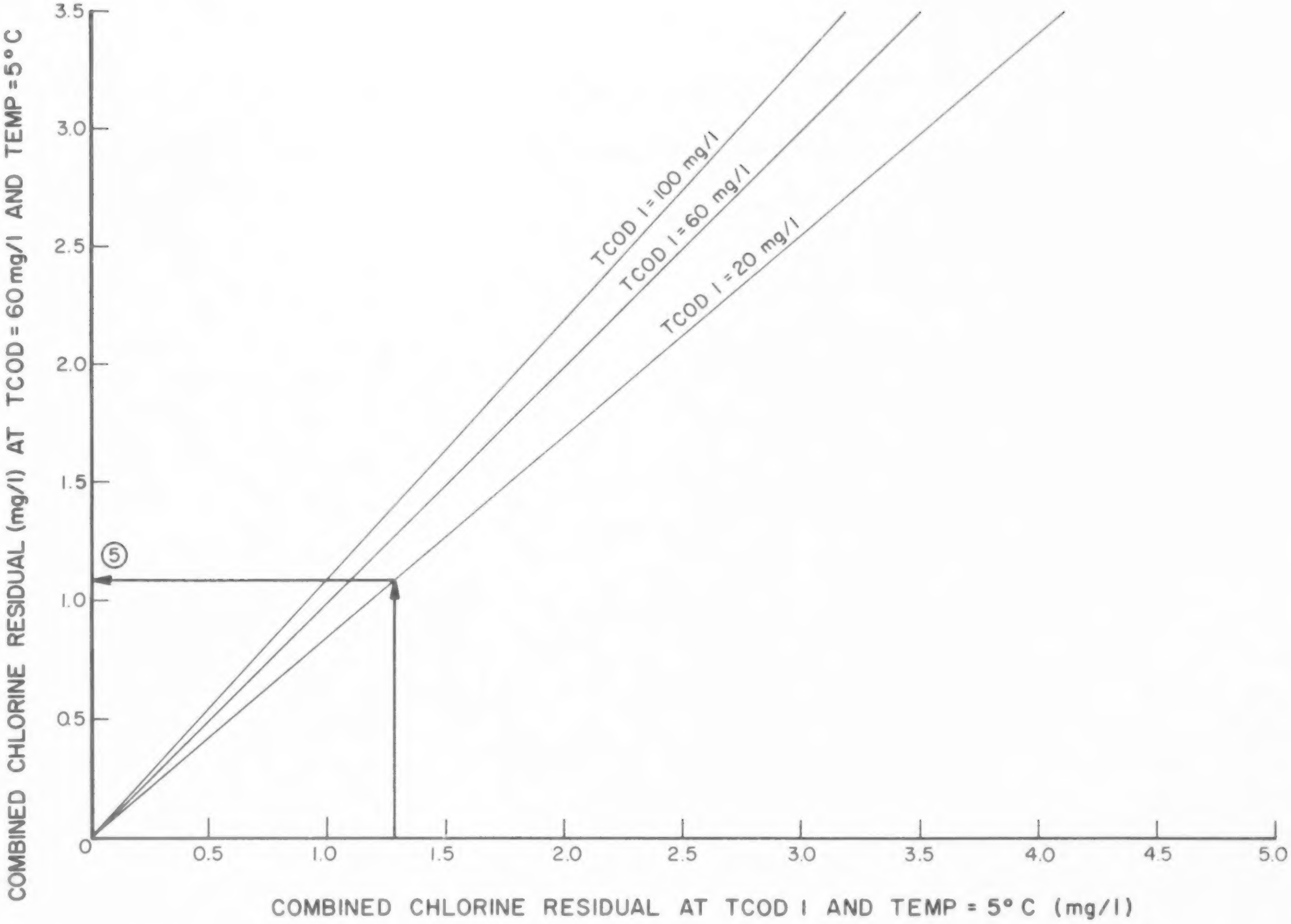


Figure 116. Conversion of combined residual chlorine at 5^{o}C and TCOD1 to equivalent residual at 5^{o}C and TCOD = 60 mg/1.

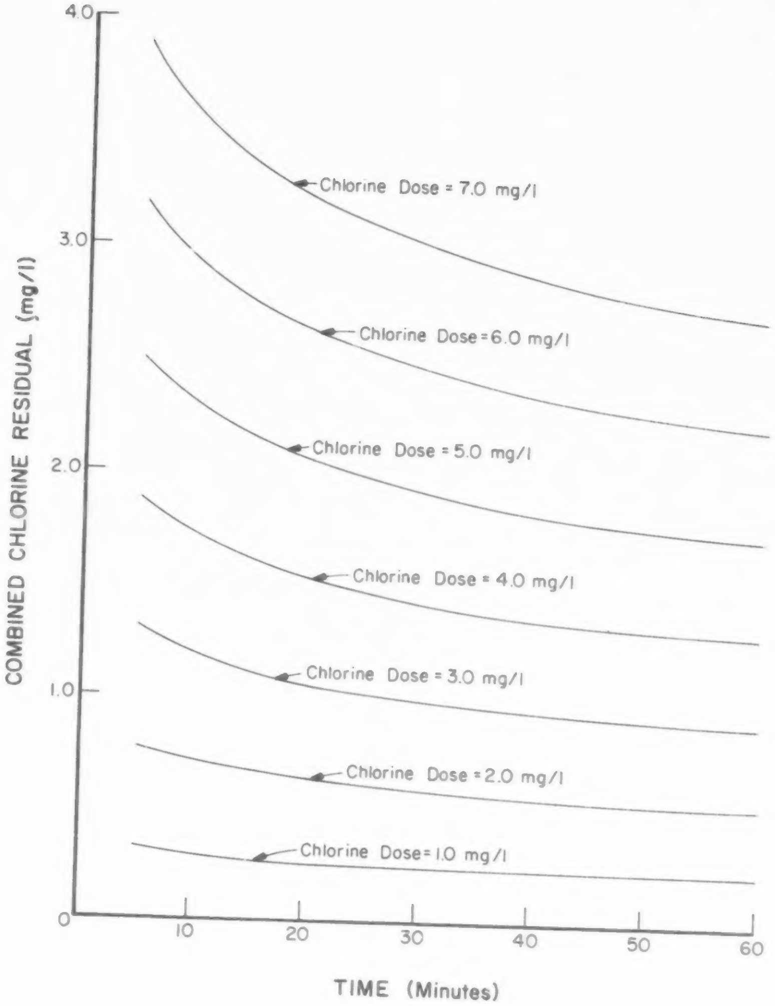


Figure 117. Determination of chlorine dose required when $S^{=}$ = 0.5 mg/l, TCOD = 60 mg/l, and Temp. = 5°C.

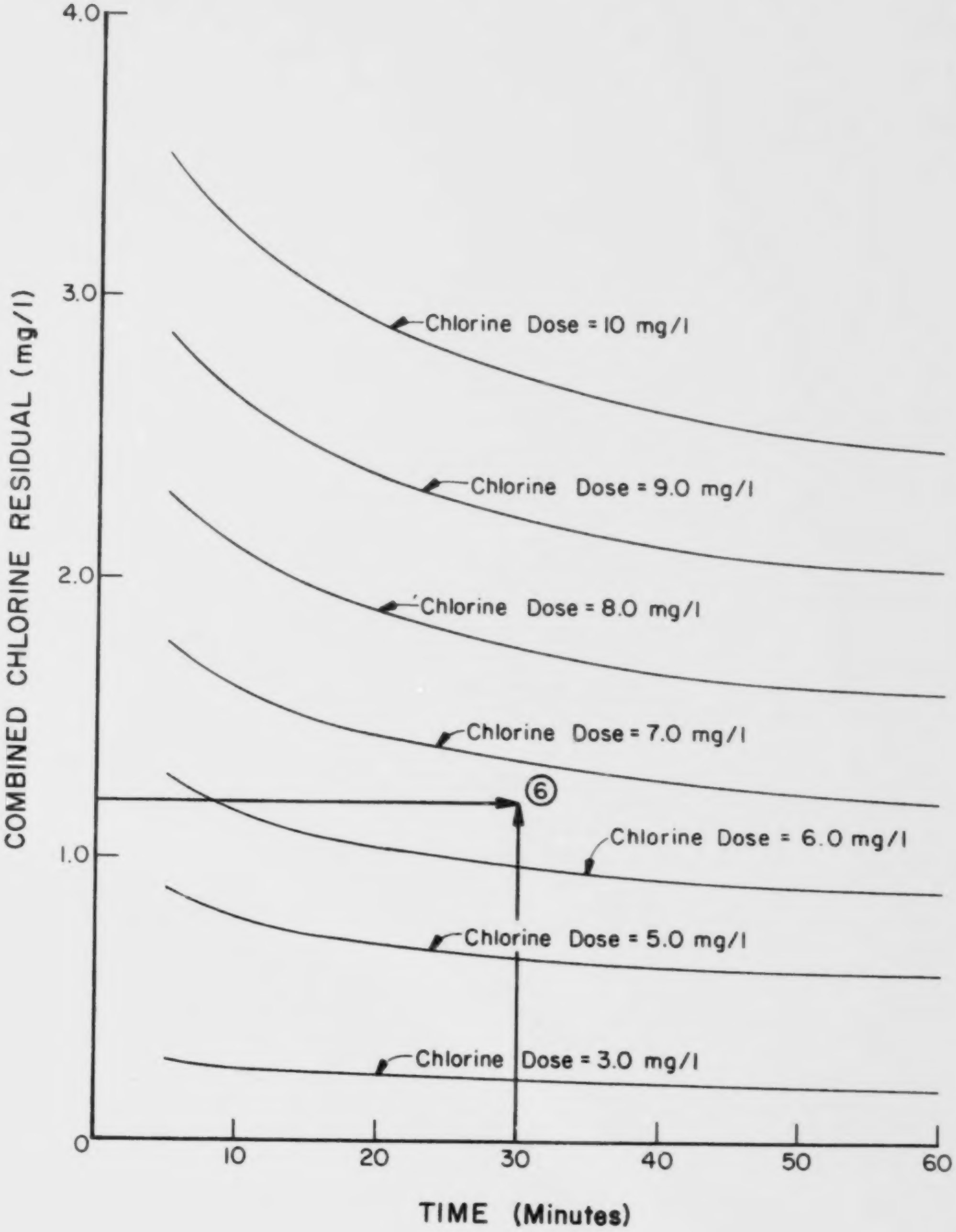


Figure 118. Determination of chlorine dose required when $S^=$ = 1.0 mg/1, TCOD = 60 mg/1, and Temp. = 5°C.

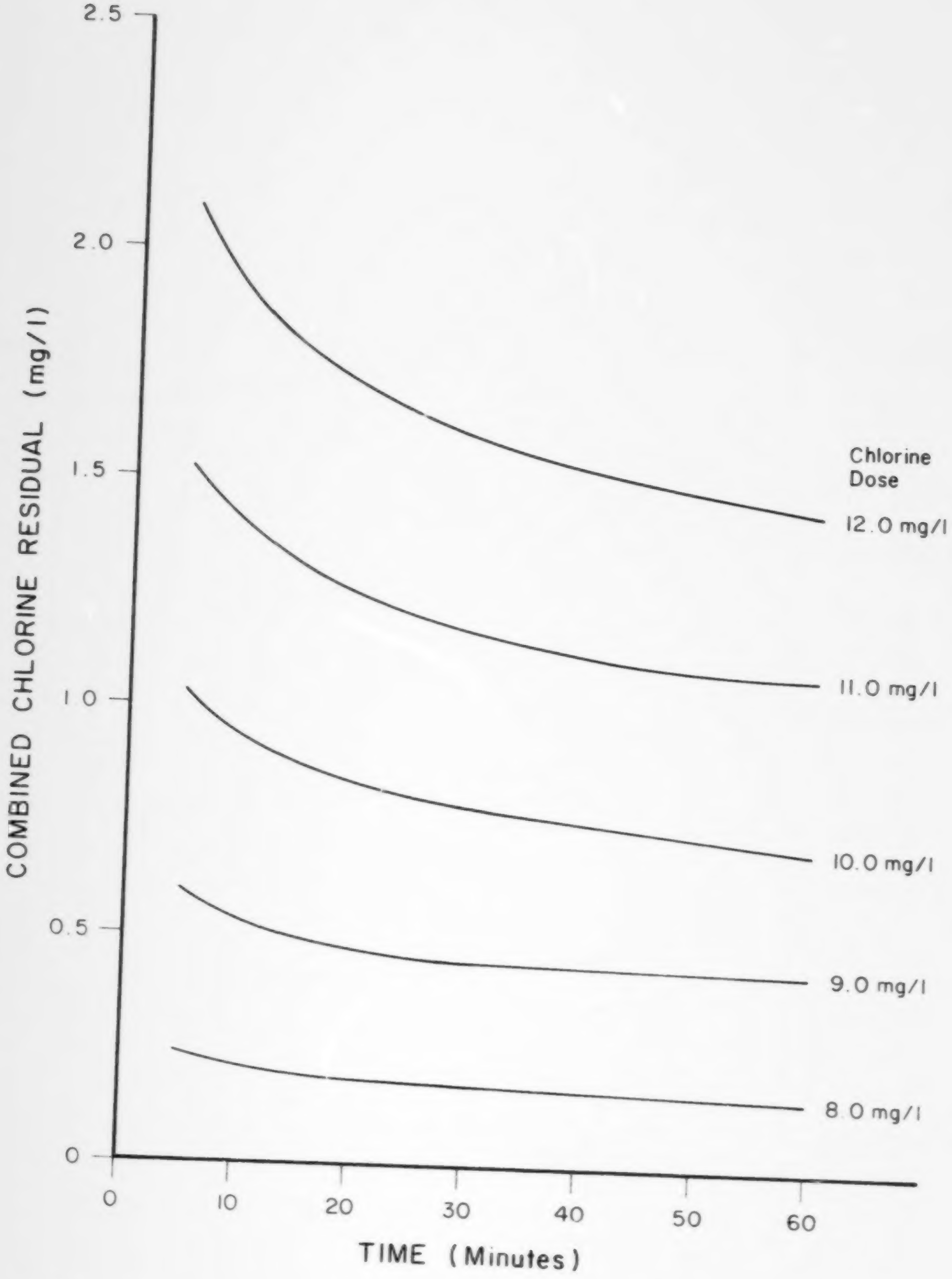


Figure 119. Determination of chlorine dose required when $S^=$ = 1.5 mg/l, TCOD = 60 mg/l, and Temp. = 5°C.

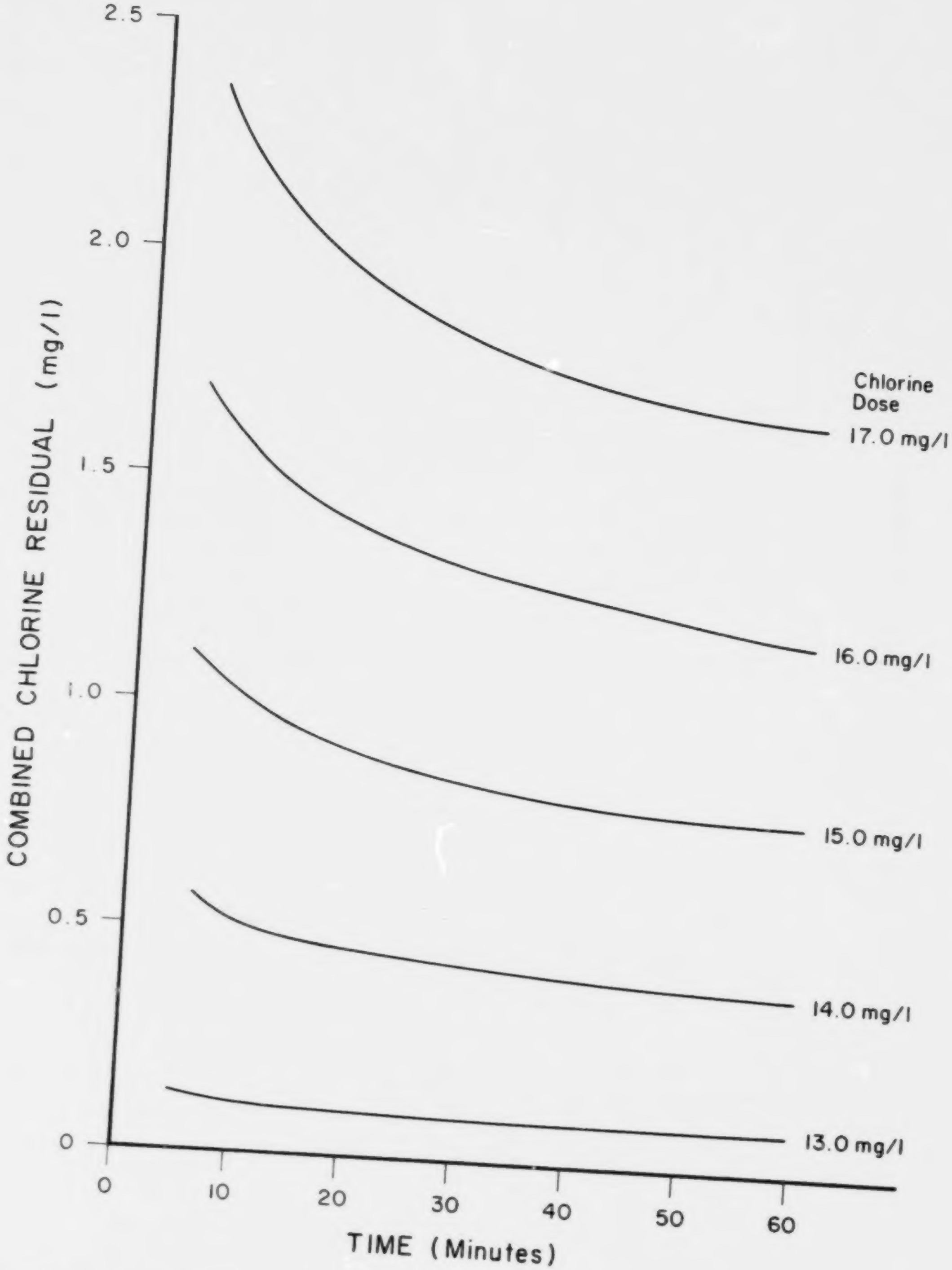


Figure 120. Determination of chlorine dose required when $S^=$ = 2.0 mg/l, TCOD = 60 mg/l, and Temp. = 5°C.

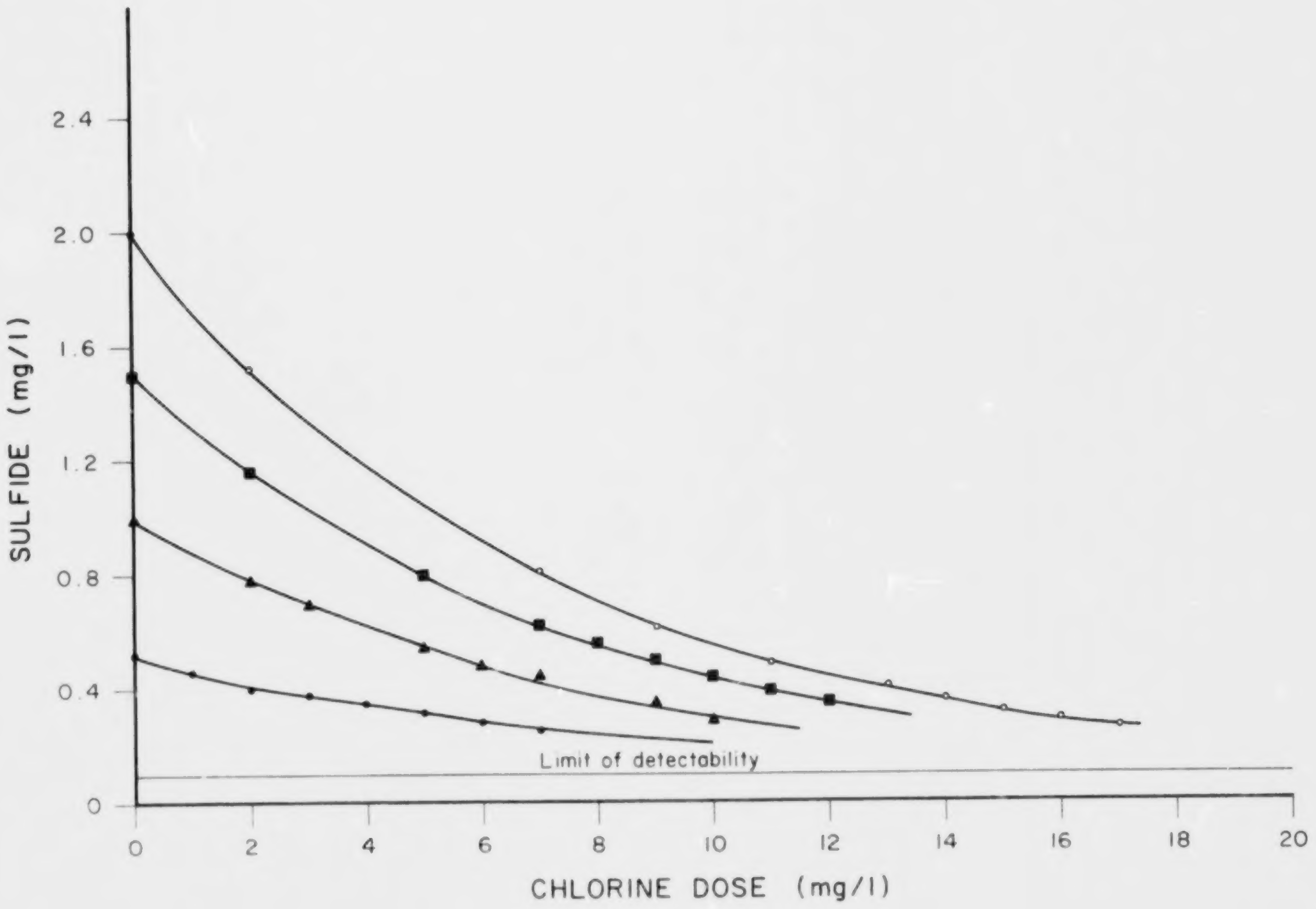


Figure 121. Sulfide reduction as a function of chlorine dose.

If there is no initial sulfide in the wastewater, it is necessary to go directly from Figure 115, after the temperature dependent residual chlorine conversion has been made, to Figure 122. Here, the residual at 20°C and any TCOD is converted to the equivalent chlorine residual that would be produced from the same chlorine dose if the TCOD was at 60 mg/l and temperature at 20°C. The desired chlorine dose required to produce the equivalent residual at 20°C and 60 mg/l TCOD is then determined for any contact period from Figure 123. This is the chlorine dose required to produce the desired level of bacterial reduction. Figure 123 is good for chlorine doses up to about 10 mg/l when NH_3-N is 1.0 mg/l or greater and the TKN is about 2.0 mg/l or greater. It also may apply for chlorine doses of less than 10 mg/l when NH_3-N concentrations are below 1.0 mg/l and TKN below 2.0 mg/l. This depends on the value of the organic nitrogen correction factor, CORNH3.

Design curves are not included for NH_3-N reduction because of the variability of CORNH3. The value for this variable must be determined experimentally for each particular quality of lagoon effluent chlorinated. Also, from field data it was determined that for most cases, adequate disinfection is achieved with very little or no reduction in NH_3-N. Changes in SS and SCOD are also not included in the design curves. This is because they are of limited importance in comparison with changes in bacteria and chlorine residual. Also, the value of F, the settling fraction, is highly variable and is of importance only when determined specifically for the lagoon effluent to be chlorinated. CHLOR-I must be applied to a particular effluent, after the determination of CORNH3 and F, if it is desired to know specifically how NH_3-N, SCOD, and SS may be expected to change.

An example may best illustrate how these design curves are applied. Assume that a particular lagoon effluent is characterized as having a fecal coliform concentration of 10,000/100 ml, 0 mg/l sulfide, 20 mg/l TCOD, and a temperature of 5°C. If it is necessary to reduce the fecal coliform counts to 100/100 ml, a combined chlorine residual sufficient to produce a 99 percent bacterial reduction must be obtained. If an existing chlorine contact chamber has an average residence time of 30 minutes, the required chlorine residual is obtained from Figure 101. A 99 percent bacterial reduction corresponds to log (N_0/N) equal to 2.0. For a contact period of 30 minutes, a combined chlorine residual of between 1.0 and 1.5 mg/l is required to produce that level of fecal coliform reduction. Upon interpolation, the actual chlorine residual is determined to be 1.30 mg/l. This is indicated by point ① in Figure 101.

Going to Figure 115, it is determined that if a chlorine dose produces a residual of 1.30 mg/l at 5°C, the same dose would produce a residual of 0.95 mg/l at 20°C. This is because of the faster rate of reaction between TCOD and chlorine at the higher temperature. This is indicated by point ② in Figure 115. For an equivalent chlorine residual of 0.95 mg/l at 20°C and 20 mg/l TCOD, it is determined from Figure 122 that the same chlorine dose would produce a residual of 0.80 mg/l if the TCOD were 60 mg/l. This is because higher concentrations of TCOD increase the rate of chlorine demand. Point ③ in Figure 122 corresponds to this residual. The chlorine dose required to produce an equivalent residual of 0.80 mg/l at 20°C and 60 mg/l TCOD is determined from Figure 123. For a chlorine contact period of 30 minutes, a chlorine dose of 2.15 mg/l is necessary to produce the desired combined residual as indicated

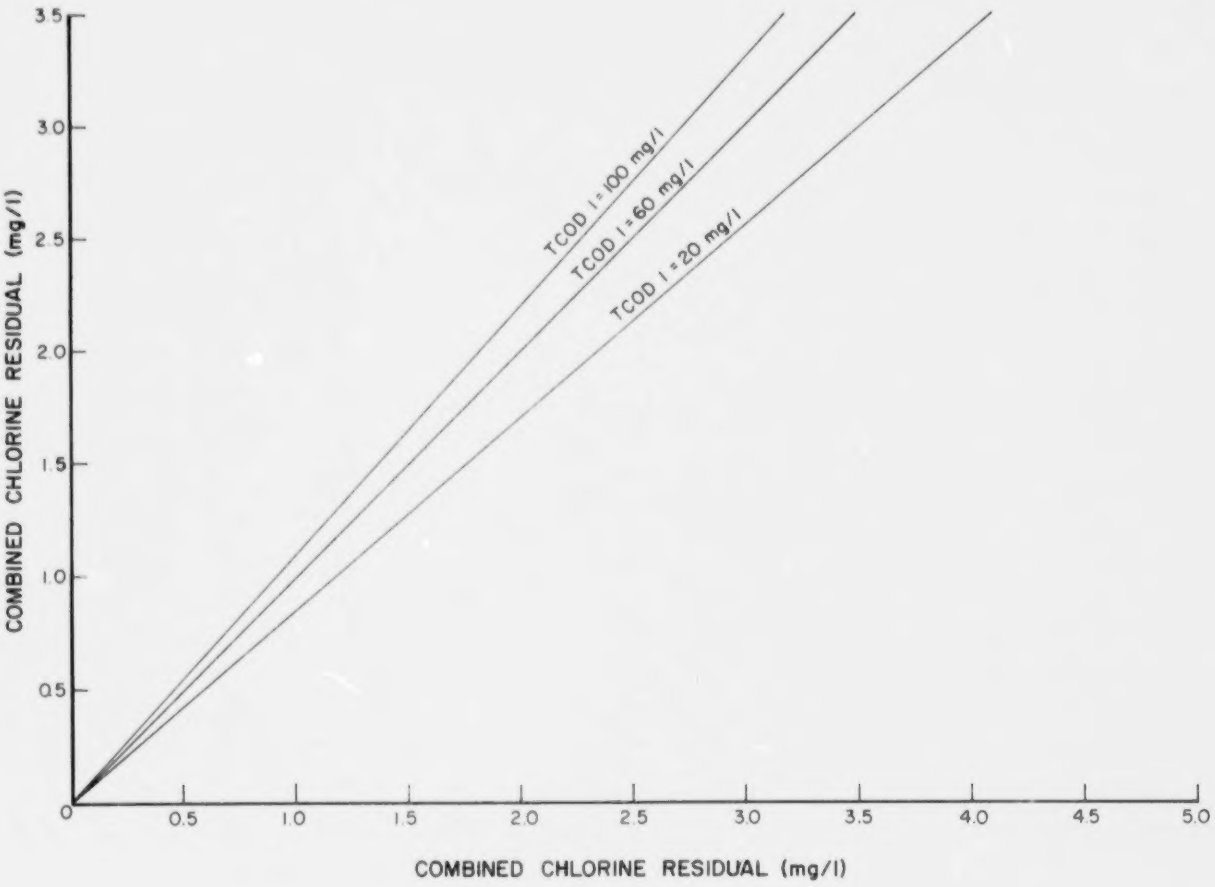


Figure 122. Conversion of combined chlorine residual at TCOD1 and 20°C to equivalent residual at 20°C and TCOD = 60 mg/1.

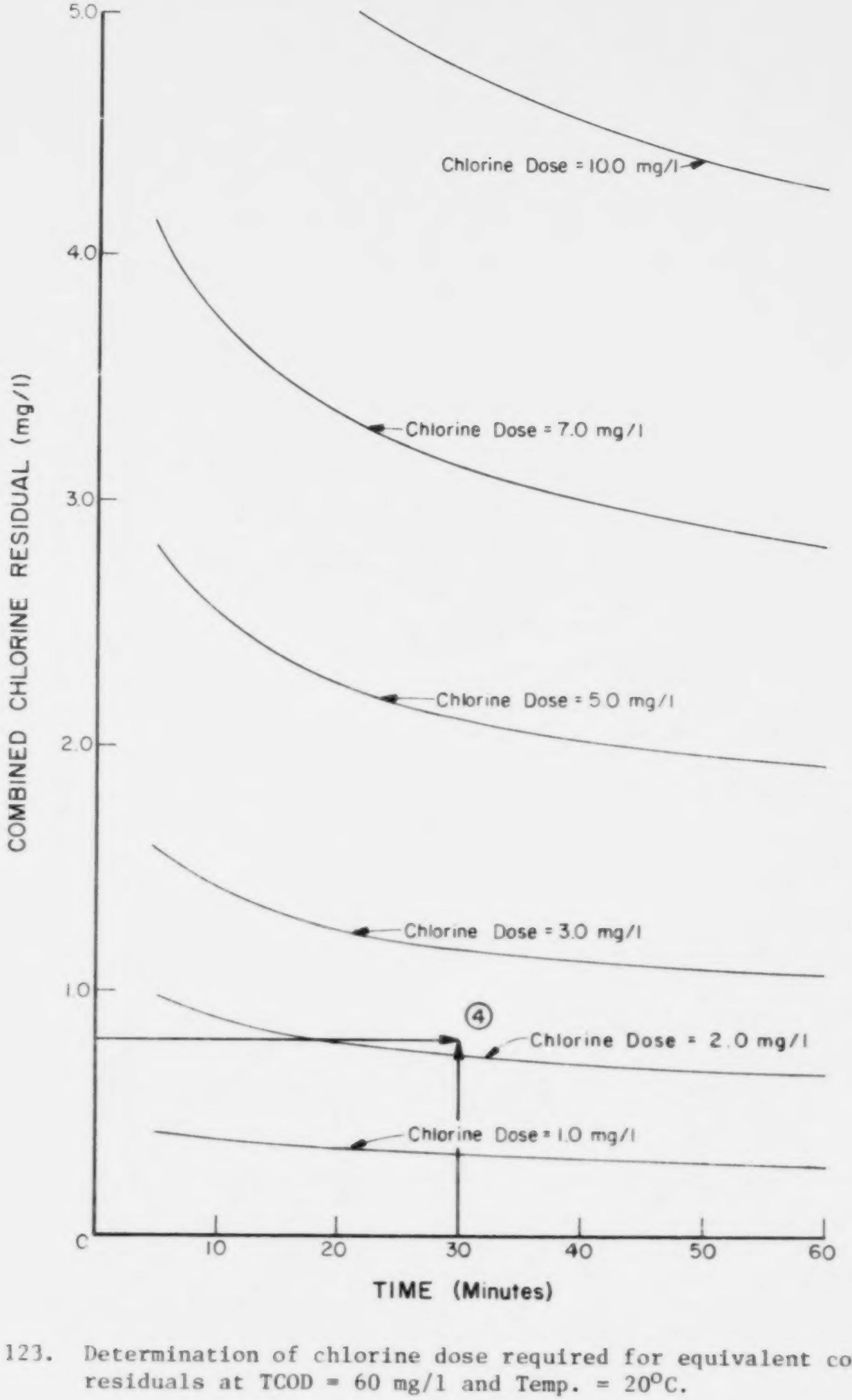


Figure 123. Determination of chlorine dose required for equivalent combined residuals at TCOD = 60 mg/l and Temp. = 20°C.

by point ④ on Figure 123. This dose will produce a reduction of fecal coliform from 10,000/100 ml to 100/100 ml within 30 minutes at 5°C and with 20 mg/l TCOD.

If, in the previous example, the initial sulfide concentration was 1.0 mg/l instead of 0 mg/l, it would be necessary to go directly from Figure 101 to Figure 116. Here, a chlorine residual of 1.30 mg/l at a TCOD of 20 mg/l and a temperature of 5°C is converted to an equivalent chlorine residual of 1.10 mg/l for a TCOD of 60 mg/l. This is represented by point ⑤ in Figure 116. Going to Figure 118, which corresponds to an initial sulfide concentration of 1.0 mg/l, it is determined that a chlorine dose of 6.65 mg/l is necessary to produce an equivalent chlorine residual of 1.1 mg/l after a contact period of 30 minutes. Point ⑥ on Figure 118 corresponds to this dose. The sulfide remaining after chlorination is determined to be 0.44 mg/l from Figure 121 as indicated by point ⑦. A summary of the sequential use of the figures for this example is contained in Table 10.

The design curves may also be used to determine the size of chlorine contact tanks. As an example, if initial conditions are the same as in the previous example and discharge requirements restrict chlorine residual to less than 1.3 mg/l in the treated effluent, it is determined from Figure 101 that a minimum detention time of 30 minutes is required to produce a 99 percent kill. Proceeding sequentially from Figure 101 to Figures 115, 122, and 123 in the same manner as described in the previous example, it is determined that for the minimum contact time, a maximum of 2.15 mg/l applied chlorine dose is required. Using economic considerations, the chlorine dose may be reduced by increasing the size of the contact tank to produce a longer detention time.

In applying these design curves, it must be realized that they were developed from data collected from one particular lagoon system. Although the data appear to be reasonably typical of that collected from other systems, variations in effluent characteristics from lagoon to lagoon may alter the chlorine dose required to achieve a desired level of disinfection. However,

TABLE 10. SUMMARY OF EXAMPLE FOR SELECTING CHLORINE DOSE FOR FECAL COLIFORM REDUCTION FROM 10^4/100 ML TO 10^2/100 ML IN 30 MINUTES

Figure No.	TCOD (mg/l)	Temp. °C	Sulfide (mg/l)	Combined Residual (mg/l)	Chlorine Dose (mg/l)
111	20	5°	0	1.30	--
125	20	20°	0	0.95	--
132	60	20°	0	0.80	--
133	60	20°	0	0.80	$\boxed{2.15}$
111	20	5°	1.0	1.30	--
126	60	5°	1.0	1.10	--
128	60	5°	1.0	1.10	$\boxed{6.65}$
131	60	5°	0.44	1.10	6.65

these curves should be useful in estimating general ranges of chlorine doses, as well as residence times required to achieve disinfection. This information can be used in designing chlorine contact tanks with the limitation that it applies only to contact chambers exhibiting plug flow hydraulic characteristics.

SECTION 7

RESULTS AND DISCUSSION OF LAGOON COLIFORM REMOVAL STUDY

GENERAL

A brief description of the Logan City Lagoon performance observed between June 1, 1975, and August 24, 1976, is contained in this section. Details are presented in tabular and graphical form in Appendix E.

OPERATION OF THE LOGAN CITY LAGOON SYSTEM

Operation of the Logan City Lagoon System is related to seasonal climatic conditions. In general, during the winter months, when the rate of biological stabilization of organic wastes is reduced due to reduced temperatures, the contents of the lagoon system are stored. This is accomplished by closing the final effluent discharge gates and eliminating any discharge from the lagoon system. Thus, because there is a constant inflow to the lagoon system the overall depth of the lagoon system is increased.

However, because the discharge between each cell within the system is controlled by an overflow weir, the water level of the last cell within the system increases before the water level in the next to the last cell increases. Thus, the stored water within the lagoon system tends to "back-up" within each cell until it is finally stored within the primary cells. As a consequence, during this winter period, the average hydraulic residence time of the final cell within the system is significantly greater than that of the primary cells.

As the temperature begins to increase during early spring and when the storage capacity of the entire lagoon system has been reached, the final effluent gates are opened and the lagoon system begins to discharge. However, during this early spring discharge, the level of the discharge weirs between the lagoon cells is reduced. Thus, the contents of each cell is discharged in a relatively short period. This rapid spring discharge tends to "flush" the lagoon system. As a result, the contents of the primary cell which have had a relatively short hydraulic residence time under low temperature conditions, tends to move through the lagoon system as a single mass or slug.

The movement of this single mass or slug through the lagoon system is accompanied by high coliform counts (10^5/100 ml) in the final lagoon effluent.

During summer and fall seasons, the lagoon system is operated as a standard flow-through lagoon and final coliform counts are less than 200/100 ml.

OVERALL LAGOON PERFORMANCE

The data indicate that COD, both soluble and total, was slightly higher in the influent between December and April than during the remainder of the year. This was probably because water from irrigation return flow and from groundwater infiltration dilutes the wastewater during summer months. BOD_5 was also found to follow the same trend, varying between a high of 100 mg/l during winter months to a low of 10 mg/l during the summer. Total COD varied between a high of 300 mg/l during the winter to a low of 20 mg/l during the summer. Soluble COD varied between 100 and 10 mg/l. The total and soluble COD in the effluent were found to be nearly equivalent, varying from 15 to 90 mg/l. Seasonal trends in effluent COD were not observed. However, seasonal variations in BOD_5 were observed with peak values occurring in early April and minimum values occurring during June. Effluent BOD varied from 2 to 23 mg/l.

Ammonia also fluctuated with the seasons. In the influent, peak ammonia concentrations of 14.5 mg/l occurred during February while minimums of less than 1.0 mg/l were observed during summer months. Effluent ammonia was observed to be approximately 3.0 mg/l during winter months and 8.0 mg/l during early spring. The increase in ammonia during early spring is attributed to the annual operation procedure for the Logan Lagoon System. During the winter months (i.e., generally January, February) the effluent gates of the final cell in the Logan Lagoon System are closed and there is no discharge from the system. Thus, the lagoon contents are stored. In early spring, the final effluent gates are opened and the stored contents are discharged over a very short period (i.e., 30 days). During the summer months, effluent ammonia decreased to less than 1.0 mg/l. Low ammonia concentration was found to correspond to algae blooms in the lagoon system.

Variations in suspended solids and volatile suspended solids also followed seasonal trends. Influent SS varied between 100 mg/l in the winter to 15 mg/l in the summer. Results were highly variable depending on the exact time when grab samples were collected. When 24 hr. composite samples were taken, the results were also found to be quite variable. In the influent, VSS was found to comprise a smaller percentage of total SS than in the effluent. The VSS in the effluent were in excess of 90 percent of the total SS. Peaks in the effluent occurred during the spring discharge resulting from winter storage and reached as high as 35 mg/l. Minimums occurred primarily during summer months when SS dropped to less than 5 mg/l.

Variation in the influent temperature was found to be minimal, varying only between 9 and 17°C during the year. For all other cells and the final lagoon effluent, the temperature varied according to air temperature. Lagoon temperatures fluctuated between 1 and 25°C.

The influent dissolved oxygen level was consistently between 2.5 to 7.3 mg/l. In other lagoon cells and final lagoon effluent, the DO varied from less than 0.2 mg/l during the winter, when ice covered the lagoons, to nearly 25 mg/l. From spring through fall, peaks in dissolved oxygen were observed to correspond to algae blooms.

The influent pH was generally between 7.5 and 8.5 during the year. In lagoon cells and final effluent, the pH varied between 7.5 and 9.5. Lowest pH values were observed during February and March, while peaks in pH occurred between May and September, depending on when algae blooms occurred. The highest pH values were associated with algae blooms.

In evaluating coliform reduction in the lagoon system, membrane filter TC and FC counts were found to be in close agreement. Occasionally membrane filter FC counts were higher than TC counts. One problem with the use of the membrane filter technique for enumerating coliforms in lagoon effluent is the extensive overgrowth of algae and other types of microorganisms on the filter. Samples containing moderate numbers of algae are difficult to filter due to clogging. Influent total and fecal coliform densities varied from 10^4 to 10^6/100 ml throughout the study. Slight reductions in the influent coliform counts were observed during the warmer months due to dilution. Total and fecal coliform numbers ranged from 10^4 to 10^5/100 ml (occasionally these numbers reached 10^6/100 ml) during these times. In the winter months, coliform counts increased approximately ten-fold.

Approximately 99.9 percent of total and fecal coliform reductions in the lagoon system occurred in the two primary cells. Further reductions in succeeding cells resulted in fecal coliform levels in the final effluent below 10/100 ml. The only exception occurred during the spring discharge, when the effluent gates in the last lagoon cell were opened to allow wastewater to flow through lagoon cells at a faster rate. During this time, fecal coliform numbers reached a high of 10^5/100 ml.

COLIFORM REMOVAL PERFORMANCE

Introduction

The objective of this part of the study was to establish representative values of the first order decay rate for fecal coliforms in the Logan City lagoon system under summer and winter conditions. A preliminary step toward achieving this objective is the estimation of inter-pond flows using an interactive flow balance model. Values for the first order decay rates are obtained by a trial-and-error calibration procedure for a fecal coliform model of the lagoon system. Estimates of the variation of retention time during summer and winter periods are also obtained. This subsection is divided into three parts: a description of the flow balance model, a description of the fecal coliform model, and a results section.

Flow Balance Model

Inflows to the lagoon system are measured before the raw wastewater enters the A ponds (Figure 124). Outflows are measured from pond E. Flows between ponds, or storage volumes in each pond, are not measured. To facilitate simulation of fecal coliform die-away, the flow rates between each pond, and the storage volume in each pond, are needed.

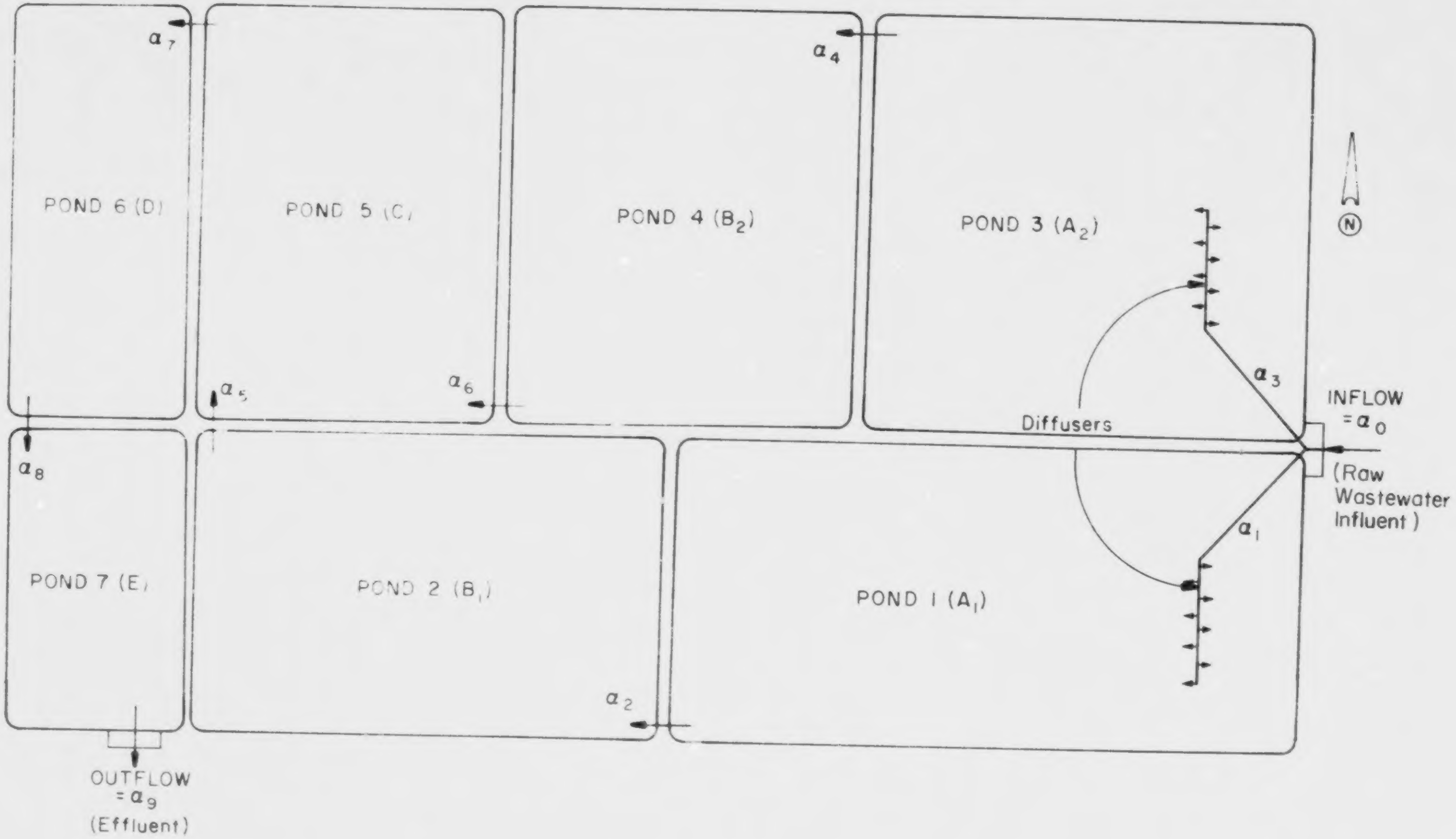

POND 6 (D)
POND 5 (C)
POND 4 (B_2)
POND 3 (A_2)
POND 7 (E)
POND 2 (B_1)
POND 1 (A_1)
a_7
a_4
a_5
a_6
a_3
a_8
a_2
a_1
Diffusers
INFLOW $= a_0$
(Raw Wastewater Influent)
OUTFLOW $= a_9$
(Effluent)
N

Figure 124. Flow diagram of Logan City wastewater lagoon system.

Direct estimation of the inter-pond flow rates and storage volumes from the inflow and outflow data for the entire system was not possible, because a set of quantitative operating procedures for the control structures between ponds could not be obtained from Logan City. Therefore, the inter-pond flows and storage volumes were estimated through an interactive simulation process using a flow balance simulation model developed for the Logan wastewater lagoon system. Figure 124 is a flow diagram of the Logan City wastewater system and also serves as a key to the "α" notation used to represent the inter-pond flows.

The flow balance model simulates the following annual cycle of operating conditions in the lagoon system:

1. All seven ponds operating.
2. Ponds D and E drawing down while the entire inflow is stored in the first five ponds ($\alpha_7 = 0$).
3. Only the first five ponds working ($\alpha_7 = \alpha_8 = \alpha_9 = 0$).
4. Filling ponds D and E from storage in the first five ponds.

Operating condition 1 applies for most of the year with the exception of the winter period of ice cover, when condition 3 applies. Generally, ponds D and E are drawn down sometime after the flow (α_7) between ponds C and D is closed off. Draw down in ponds D and E is represented by operating condition 2. During the winter period levels in the first five ponds rise until the flow (α_7) into ponds D and E is restarted. At this time, wastewater with fairly high coliform levels passes into ponds D and E, and the effluent is characterized by a transient period of high coliform levels. The previous draw down of ponds D and E tends to reduce the coliform levels slightly by providing some storage for the high coliform water before it becomes effluent. Operating condition 4 represents the filling of ponds D and E from storage in the first five ponds. Other operating conditions are possible but the four conditions described above are the most important for the period of the flow balance (June 1975 - June 1976).

The following sections describe the flow balance equations used to simulate each operating condition on a daily basis. Notation used below is as follows:

A_i = water surface area of the ith pond
v_i = volume of wastewater stored in the ith pond
V_i = capacity of the ith pond
e = pan evaporation depth measured at Utah State University Experiment Station

Operating Condition 1--

Change of storage through the entire system: $DQ = \alpha_o - \alpha_9$ . . . (89)

Assumption: the fraction of DQ stored in the ith pond is proportional to the ratio of the capacity of the ith pond to the capacity of the entire system

Inter-pond flows:
$$\alpha_1 = \alpha_0/2 \tag{90}$$

$$\alpha_2 = \alpha_1 - DQ * V_1/\sum_{i=1}^{7} V_i \tag{91}$$

$$\alpha_5 = \alpha_1 - DQ * \sum_{i=1}^{2} V_i/\sum_{i=1}^{7} V_i \tag{92}$$

$$\alpha_3 = \alpha_0/2 \tag{93}$$

$$\alpha_4 = \alpha_3 - DQ * V_3/\sum_{i=1}^{2} V_i \tag{94}$$

$$\alpha_6 = \alpha_3 - DQ * \sum_{i=3}^{4} V_i/\sum_{i=1}^{7} V_i \tag{95}$$

$$\alpha_7 = \alpha_0 - DQ * \sum_{i=1}^{5} V_i/\sum_{i=1}^{7} V_i \tag{96}$$

$$\alpha_8 = \alpha_0 - DQ * \sum_{i=1}^{6} V_i/\sum_{i=1}^{7} V_i \tag{97}$$

Operating Condition 2--

(a) First five ponds.

Change in storage:
$$DQ = \alpha_0 \tag{98}$$

Assumption: the fraction of DQ stored in the ith pond is proportional to the ratio of the capacity of the ith pond to the total capacity of the first five ponds

Inter-pond flows:
$$\alpha_1 = \alpha_0/2 \tag{99}$$

$$\alpha_2 = \alpha_1 - DQ * V_1/\sum_{i=1}^{5} V_i \tag{100}$$

$$\alpha_5 = \alpha_1 - DQ * \sum_{i=1}^{2} V_i/\sum_{i=1}^{5} V_i \tag{101}$$

$$\alpha_3 = \alpha_0/2 \tag{102}$$

$$\alpha_4 = \alpha_3 - DQ * V_3/\sum_{i=1}^{5} V_i \tag{103}$$

$$\alpha_6 = \alpha_3 - DQ * \sum_{i=3}^{4} V_i/\sum_{i=1}^{5} V_i \tag{104}$$

$$\alpha_7 = 0 \quad \text{. . . . .(105)}$$

(b) Ponds D and E

Change in storage: $DQ' = \alpha_9$ . . . .(106)

Assumption: the fraction of DQ' from the ith pond is proportional to the ratio of the capacity of the ith pond to the combined capacity of ponds D and E

Inter-pond flow: $\alpha_8 = DQ' * V_6 / \sum_{i=6}^{7} V_i$ . . . .(107)

Operating Condition 3--

(a) First five ponds

Identical to 2(a)

(b) Ponds D and E

Assumption: no flow into or out of ponds D and E

Inter-pond flow: $\alpha_8 = 0$ . . . .(108)

Operating Condition 4--

Assumptions: 1) inter-pond flows are basically as calculated under operating condition 1

2) ponds D and E are filled by augmenting the α_7 calculated under assumption 1 with a flow of Q7. This flow comes from the first five ponds, the contribution from the ith pond being proportional to the ratio of the volume of wastewater in the ith pond to the total volume of wastewater in the first five ponds. The fraction of Q7 stored in pond D is proportional to the ratio of the capacity of pond D to the capacity of ponds D and E. The remainder of Q7 is stored in pond E.

Inter-pond flows: the values for α_1 through α_7 calculated under operating condition 1 are modified using the following equations:

$$\alpha_2 = \alpha_2 + Q7 * v_1 / \sum_{i=1}^{5} v_i \quad \text{. . . . .(109)}$$

$$\alpha_5 = \alpha_5 + Q7 * \sum_{i=1}^{2} v_i / \sum_{i=1}^{5} v_i \quad \text{. . . . .(110)}$$

$$\alpha_4 = \alpha_4 + Q7 * v_3 / \sum_{i=1}^{5} v_i \quad \text{. . . . .(111)}$$

$$\alpha_6 = \alpha_6 + Q7 * \sum_{i=3}^{4} v_i / \sum_{i=1}^{5} v_i \quad \ldots\ldots (112)$$

$$_7 = \alpha_7 + Q7 \quad \ldots\ldots (113)$$

$$\alpha_8 = \alpha_7 - (\alpha_7 - \alpha_9) * V_6 / \sum_{i=6}^{7} V_i \quad \ldots\ldots (114)$$

The new volume of each pond is calculated from the previous day's volume using the following flow balance equations, which include a term for the evaporation losses:

$$v_1 = v_1 + \alpha_1 - \alpha_2 - A_1 * e, \; v_1 \geq 0 \quad \ldots\ldots (115)$$

$$v_2 = v_2 + \alpha_2 - \alpha_5 - A_2 * e, \; v_2 \geq 0 \quad \ldots\ldots (116)$$

$$v_3 = v_3 + \alpha_3 - \alpha_4 - A_3 * e, \; v_3 \geq 0 \quad \ldots\ldots (117)$$

$$v_4 = v_4 + \alpha_4 - \alpha_6 - A_4 * e, \; v_4 \geq 0 \quad \ldots\ldots (118)$$

$$v_5 = v_5 + \alpha_5 - \alpha_6 - \alpha_7 - A_5 * e, \; v_5 \geq 0 \quad \ldots\ldots (119)$$

$$v_6 = v_6 + \alpha_7 - \alpha_8, \; v_6 \geq 0 \quad \ldots\ldots (120)$$

$$v_7 = v_7 + \alpha_8 - \alpha_9, \; v_7 \geq 0 \quad \ldots\ldots (121)$$

Values for the water surface area (A) and capacity (V) of each pond are given in Table 11. Calculated values for the pond volumes are expressed as a volume ratio, as follows:

$$\gamma_i = \frac{v_i}{V_i} \quad \ldots\ldots (122)$$

Initial values for the pond volumes are also expressed in the ratio form of Equation 122.

From a study of the flow data, discussions with Logan City, and interactive simulation, the dates on which operating conditions were changed from one type to another were approximated. These dates are as follows:

1/06/76	condition 1/condition 3
2/19/76	condition 3/condition 2
3/09/76	condition 2/condition 4
3/23/76	condition 4/condition 1

Another variable which was estimated during the interactive simulation procedure was Q7. The basis for estimating Q7 is that the volume ratios in ponds D and E should be approximately equal to the volume ratios in the other ponds

TABLE 11. WATER SURFACE AREA AND CAPACITY OF EACH POND IN THE LOGAN CITY SEWAGE LAGOON SYSTEM

i	Pond	Water Surface Area (A_i) (Hectares)	Capacity (V_i) (m^3)
1	A_1	38.5	704,000
2	B_1	28.7	586,000
3	A_2	38.4	703,000
4	B_2	29.3	598,000
5	C	26.1	580,000
6	D	15.9	384,000
7	E	11.5	297,000
Total		188.4	3,852,000

Meters x 3.281 = feet; Hectares x 2.471 = acres; Meters^3 x 35.31 = feet^3

at the end of the filling period (operating condition 4). The value obtained for Q7 is 15.0 cfs.

The initial values of the volume ratios for the first day of the simulation (June 12, 1975) were not available. Therefore, these initial conditions were estimated on the basis of the operating rules used by Logan City, and then refined during interactive operation of the flow balance model. Two criteria were established to guide the refinement of the initial conditions:

1. Maximum volume ratios should be close to unity.

2. Volume ratios one year after the commencement of the simulation should be approximately the same as the initial volume ratios.

As a result of this procedure the initial volume ratios for all ponds were estimated to be 0.8. Volume ratios and inter-pond flows calculated by the flow balance model were read as input by the fecal coliform model of the lagoon system.

Fecal Coliform Model

Hydraulic Submodel--

Actual hydraulic characteristics of the Logan lagoon system are quite complex. During a dye study Mangelson (1971) observed short circuiting in the Logan lagoons. He concluded that the degree of short circuiting is influenced by wind, the relative positions of the inlet and outlet, and density stratification. Each pond may be considered to consist of two parts:

1. A dead space through which negligible flow takes place.

2. An effective space through which most of the flow takes place.

It was assumed that the effective space is a fixed proportion of the total volume of wastewater in a pond, according to the following relationship:

$$v_{eff,i} = C_{eff,i}\, v_i \quad \ldots\ldots\ldots\ldots \quad (123)$$

in which

$C_{eff,i}$ = proportionality constant
$v_{eff,i}$ = effective volume in the ith pond

A precise hydraulic model for the Logan lagoon system would require extensive tracer experiments, wind data at the site of the lagoon system, and flow measurements between each pond. Since none of these were practical within the limitations of this project, it was decided to adopt a simple plug flow model. Under this assumption the effective space in a pond is considered to comprise a series of slugs of wastewater, where each slug entered the pond on a different day (Figure 125). On each day, a new slug of wastewater with the volume of the inflow on that day enters the pond. Outflow from the pond is equal to the outflow calculated by the flow balance model, and is made up from one or more slugs nearest to the outlet. With each day that passes existing slugs in the pond move closer to the outlet and eventually enter the next pond in the system. No mixing between adjacent slugs is simulated although some mixing between the dead space and the effective space is represented to keep the total volume of the slugs consistent with the effective volume calculated in Equation 123.

Coliform Submodel--

Bacterial reduction in stabilization ponds depends on many factors. Among these factors are: retention time, water temperature, composition of algae populations, predators, sunlight, and aerobic-anaerobic nature of the wastewater. The model used in this study is based on Chick's law and does not explicitly consider the last two factors although these will affect the value used for the decay rate (K_{20}). Thus, the reduction of the coliform level in each slug is simulated using the following equation:

$$\frac{dN_{ij}}{dt} = -K_{20}\,\theta^{(T_i - 20^{\circ}C)}\,N_{ij} \quad \ldots\ldots\ldots\ldots \quad (124)$$

in which

N_{ij} = fecal coliform in the jth slug of the ith pond
t = time
K_{20} = first order decay rate for all ponds at 20°C
θ = empirical temperature correction coefficient (= 1.072)
T_i = wastewater temperature in the ith pond

Results

Since coliform levels were generally very small in ponds D and E, it was decided to model only the first five ponds. To establish representative values of K_{20} for both summer and winter conditions, two periods were simulated:

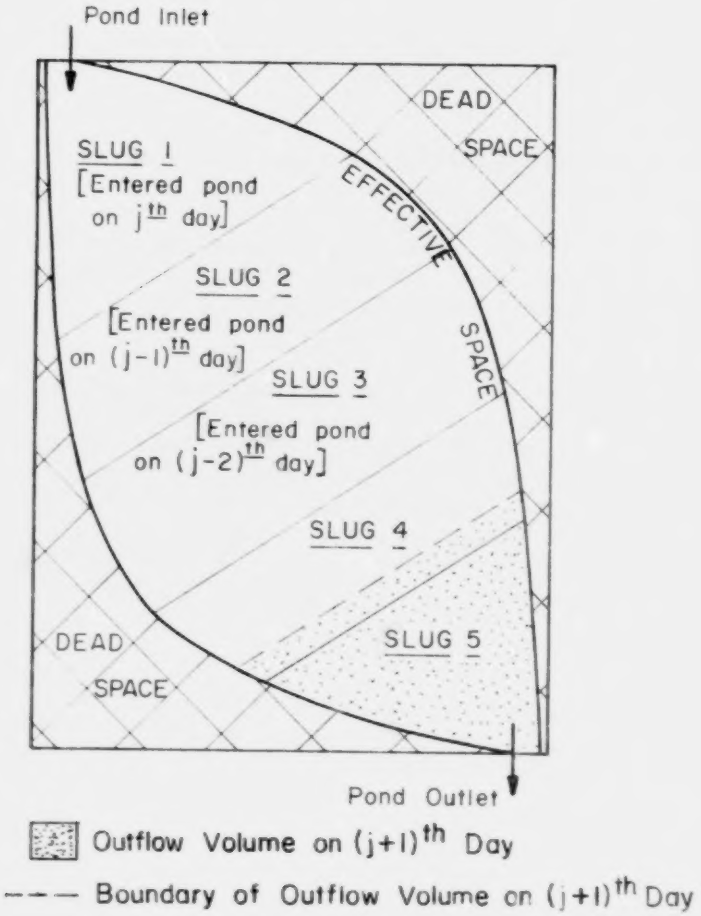

Pond Inlet
DEAD SPACE
SLUG 1
[Entered pond on j^th day]
EFFECTIVE SPACE
SLUG 2
[Entered pond on (j-1)^th day]
SLUG 3
[Entered pond on (j-2)^th day]
SLUG 4
SLUG 5
DEAD SPACE
Pond Outlet
Outflow Volume on (j+1)^th Day
--- Boundary of Outflow Volume on (j+1)^th Day

Figure 125. Schematic of the dead and effective spaces, and plug flow through a pond.

1. Summer period (6/12/75 - 9/9/75)
2. Winter period (1/2/76 - 2/19/76)

During the summer period inflows are high due to the infiltration of irrigation water. Evaporation constitutes an important loss of water from the ponds during the summertime.

The coliform model was calibrated to the summer period by adjusting the decay rate (K_{20}) and the proportionality constants for each pond ($C_{eff,i}$). Model performance was assessed by inspection of the graphs of calculated and measured coliform levels leaving each pond, and by comparison of the values of the mean square error between the calculated and measured coliform values in successive model runs. The model was validated for the winter period using the $C_{eff,i}$ values established during the summer period simulation, but using a new value for K_{20} to represent the slower rate of bacterial decay during the winter period.

The following factors should be considered when evaluating the adequacy of the simulation results:

1. Fecal coliform data used in this simulation study were obtained using the membrane filter technique. Results from this analytical procedure probably have an accuracy represented by a high coefficient of variation of 0.5 - 0.1.

2. Fecal coliform samples from lagoon inflow and the effluents from each pond were taken only twice weekly (Tuesdays and Thursdays) but the model has a daily time step. For about 25 percent of the sample days, one or more of the coliform samples were invalidated (due to lack of sample, experimental error, etc.) during the analytical procedures. Fecal coliform levels in the lagoon inflow are approximated on days without sampling by using the measured coliform value from the most recent sample. This procedure may lead to very inaccurate inflow levels since actual coliform levels in the input vary considerably from day to day.

3. Coliform levels for the slugs in a pond were initialized by a logarithmic interpolation between the observed coliform levels in the inflow and outflow of the pond. Again, these values may be very inaccurate because of the high variability in daily coliform levels of the inflow.

4. The hydraulic characteristics of the lagoon system are complex, but because of data limitations they are approximated by a simple plug flow model. Effective volumes are assumed to be a fixed proportion of the total volume of wastewater in a pond. Inter-pond flows and total volumes are approximated using the interactive flow balance model.

5. The coliform model combines the many factors affecting bacterial die-off into a simple first order decay model. Sedimentation and resuspension are therefore incorporated into the first order decay process. However, this assumption is considered to be consistent with the accuracy and availability of coliform and flow data.

6. Coliform levels in the dead space of the ponds are neglected. This is justified because coliform levels in the effective space are presumed much higher than coliform levels in the dead space.

7. The selection of a K_{20} value and $C_{eff,i}$ values during calibration of the coliform model is complicated by the problem of balancing the similar effects of a high decay rate (K_{20}) and a small retention time (and hence small $C_{eff,i}$'s), or conversely a low decay rate and a large retention time.

In an attempt to address the last factor listed above, the values of $C_{eff,i}$ obtained by Mangelson (1971) during a dye study in August, 1970, on ponds A1 and A2 were used as a guide for establishing the $C_{eff,i}$ values for the 1975 summer period. Table 12 contains the values of the model coefficients obtained for the summer and winter periods. $C_{eff,i}$ values are the same for both periods with the exception of pond C. For the winter period, $C_{eff,c}$ was increased to 1.0 to represent the situation of pond C having no outflow since $\alpha_7 = 0$. The very small value of $C_{eff,c}$ for the summer period is a result of the combined flow from the two parallel systems, A1-B1 and A2-B2, flowing through pond C which has a smaller capacity than the upstream ponds. $C_{eff,i}$ values for ponds A1 and A2 may be compared with Mangelson's values of 0.6 for pond A1 and 0.8 for pond A2 based on the passage of 50 percent of the dye and including a correction for the loss of dye by mixing with the bottom sludge.

The winter period value for K_{20} is much lower than the summer period value. This is expected because during the very cold winter period little reduction takes place except that due to sedimentation.

Results for the summer period of simulation are shown graphically in Figure 126 and for the winter period in Figure 127. Two types of plots are presented:

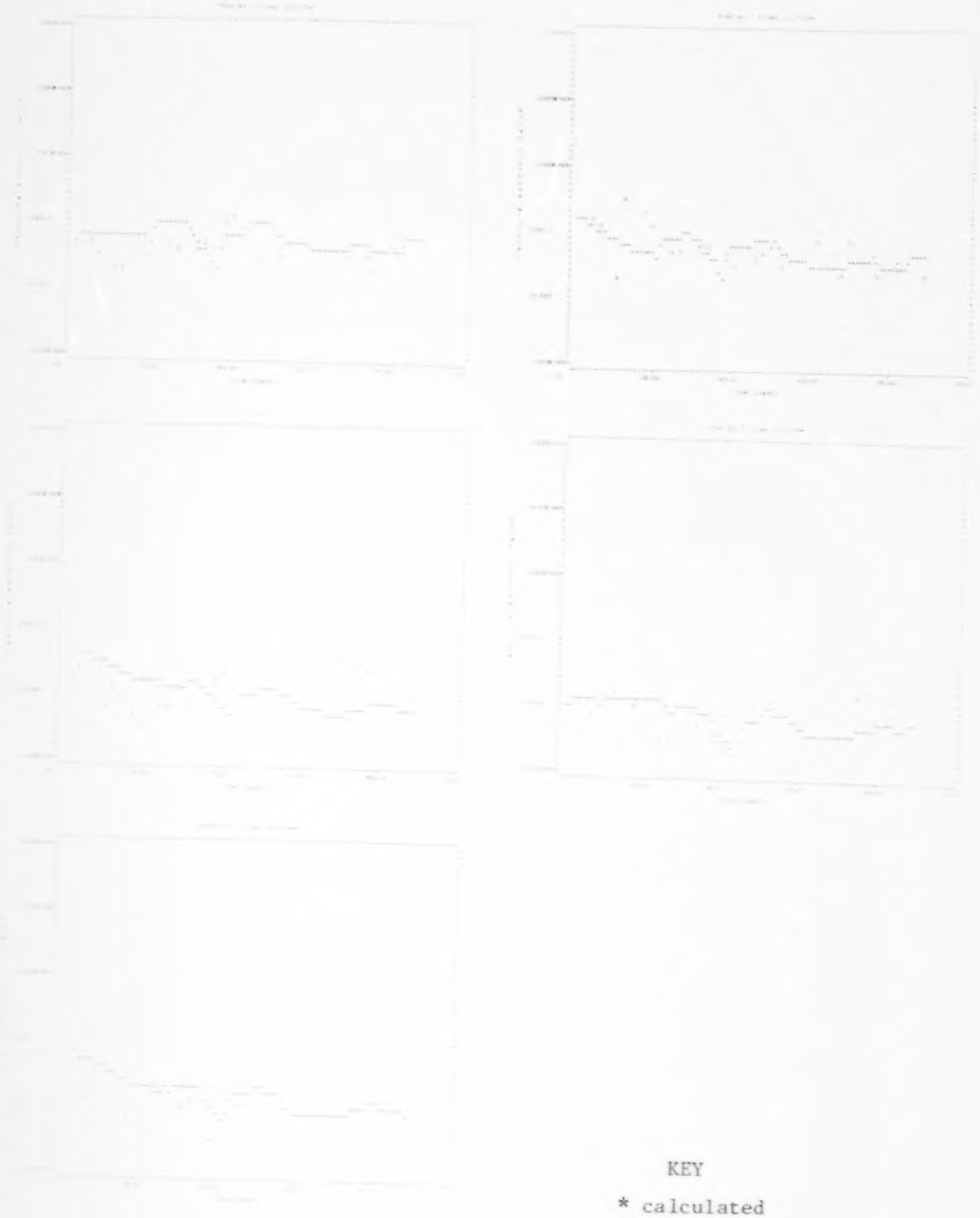
1. Calculated and measured coliform in pond outflow vs. time (Figures 126a and 127a).

2. Retention time in pond vs. time (Figures 126b and 127b).

The results presented in Figures 126a and 127a were obtained through a trial-and-error minimization of the mean square error between the calculated and observed coliform values by varying the K_{20} and $C_{eff,i}$ coefficients. From Figure 126a it will be observed that, in general, the adequacy of the calculated values of coliforms decreases through the lagoon system. That is, the measured values are better approximated by the model for the A ponds than for

TABLE 12. MODEL COEFFICIENTS FOR THE SUMMER AND WINTER PERIODS

Model Coefficient	Summer Period	Winter Period
K_{20} (Per Day)	0.50	0.03
$C_{eff,A1}$	0.65	
$C_{eff,B1}$	0.40	
$C_{eff,A2}$	0.70	
$C_{eff,B2}$	0.25	
$C_{eff,C}$	0.05	1.00



KEY

* calculated
0 measured

Figure 126a. Simulation results for the summer period (6/12/75 - 9/9/75)--calculated and measured coliform vs. time.

Figure 126b. Simulation results for the summer period (6/12/75 - 9/9/75)--retention time vs. time.

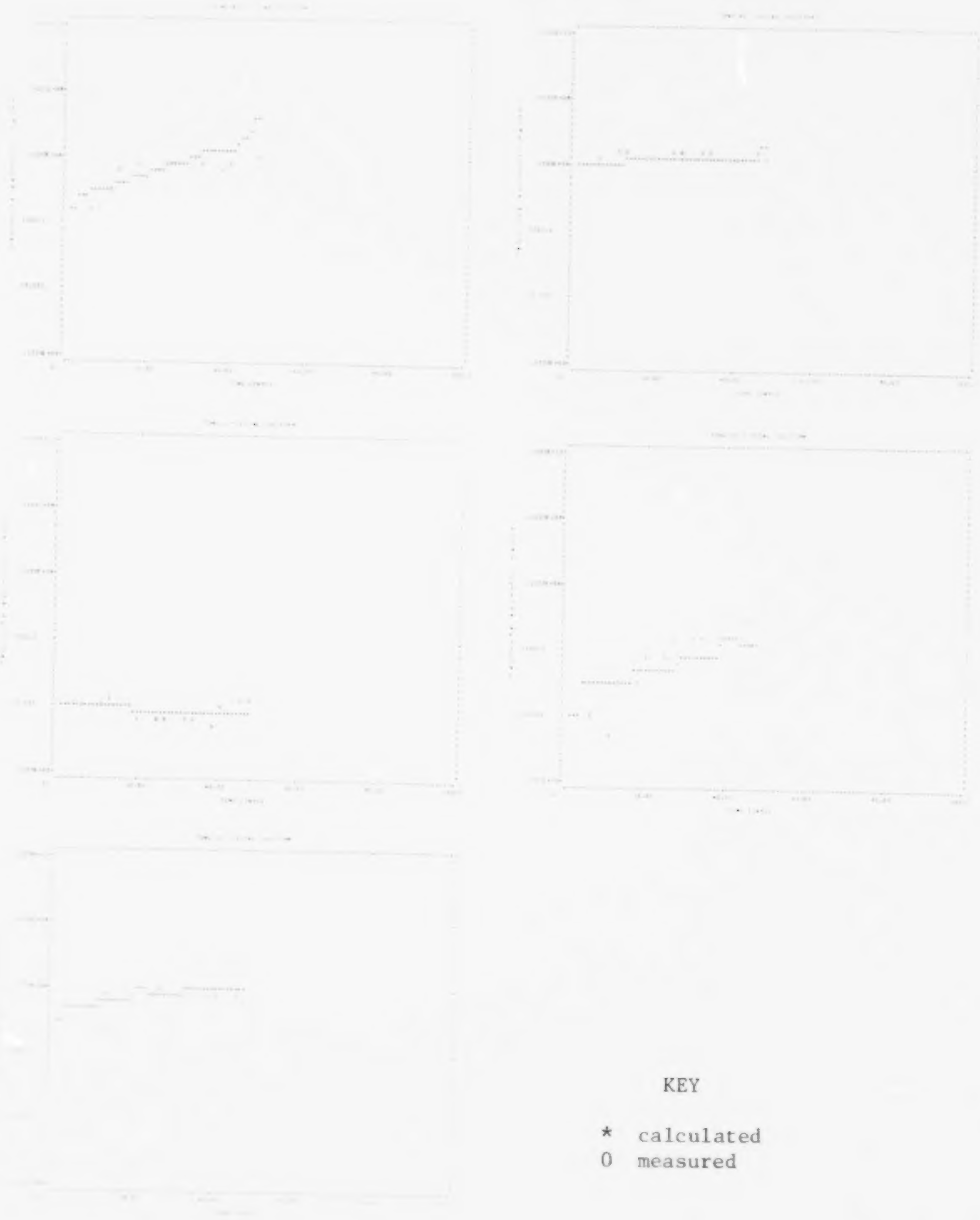


Figure 127a. Simulation results for the winter period (1/2/76 - 2/19/76)--calculated and measured coliform vs. time.

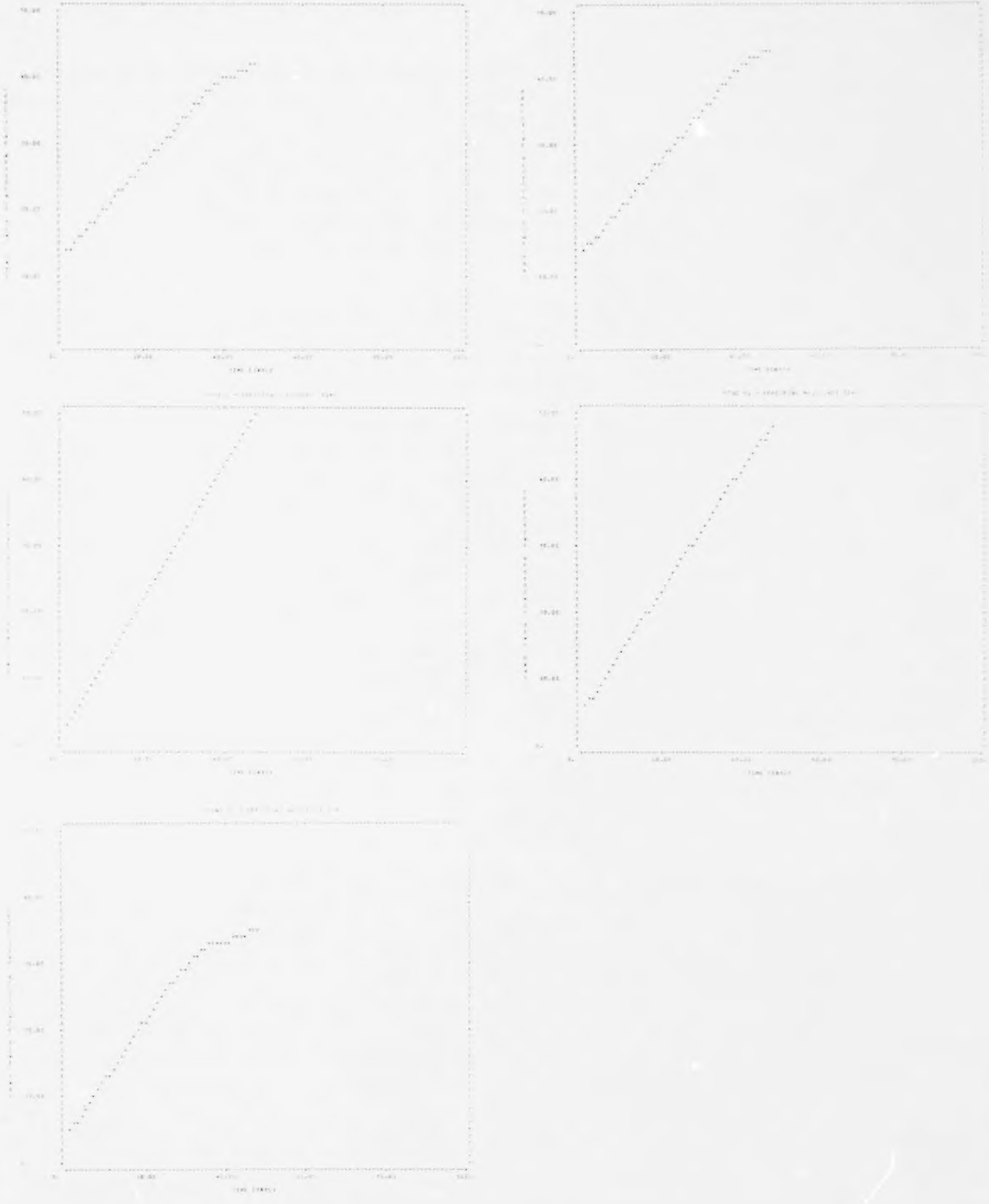


Figure 127b. Simulation results for the winter period (1/2/76 - 2/19/76)--retention time vs. time.

pond C. This characteristic is due to the accumulation of model errors through the lagoon system.

During the winter period coliform levels from pond C were measured in samples taken from water leaking through the closed outflow structure between pond C and pond D. These samples were characterized by very low coliform levels, probably because the leakage came from dead space in pond C adjacent to the outflow structure. Since the small outflow from pond C is neglected in the model, the results for pond C shown in Figure 127a are the coliform levels in the slug adjacent to the outflow structure. Coliform levels in this slug decay exponentially from their initial value at the beginning of the winter period.

The number of slugs in a pond is used as an estimate of the retention time in each pond. This estimate of retention time appears to be more realistic than dividing the effective volume by the outflow rate, especially during the winter period when outflows become quite small and are zero for pond C.

The calculated values of retention time show little variation during the summer period when inflow, outflow, and evaporation rates are all fairly uniform. During the winter period the retention time increases because outflow from pond C (α_7), and evaporation are both zero, and therefore the entire inflow is stored. Thus, for pond C the increase in retention time is linear with time from the day on which outflow from pond C was closed off. There is little difference between the retention times for ponds A1 and A2 because the effective volumes in both ponds are similar. Although the travel path between inlet and outlet in pond A1 is longer than for pond A2, the diffusers used in both ponds appear to roughly equalize the effective volumes, and therefore, the retention times. The retention time in pond B1 is greater than the retention time in pond B2 as would be expected because of the greater inlet-outlet distance in pond B1.

On the basis of the retention times estimated for the winter period, the total retention time for the first five ponds averages 80 days during the winter period when the outflow from pond C is closed off. The average total retention time for the first five ponds during the summer period is about 22 days.

Figures 128 and 129 are based on Equation 124 for the summer and winter periods, respectively. They show the number of days retention time required in the Logan lagoon system to reduce influent coliform levels to a required effluent coliform level. In each case, the K_{20} value used is the value contained in Table 12, and the temperature (T) is typical for the period. As an example, to reduce an influent coliform level of 10^7/100 ml to an effluent coliform level of 10^2/100 ml, 23 days retention time would be required under summer conditions (see Figure 128). From Figure 129 it is evident that coliform decay during the winter period is very slow.

Summary

Data were collected for a 15 month period to determine the coliform removal efficiency of the Logan lagoon system. A mathematical model was developed which describes the coliform die-away through the lagoon system.

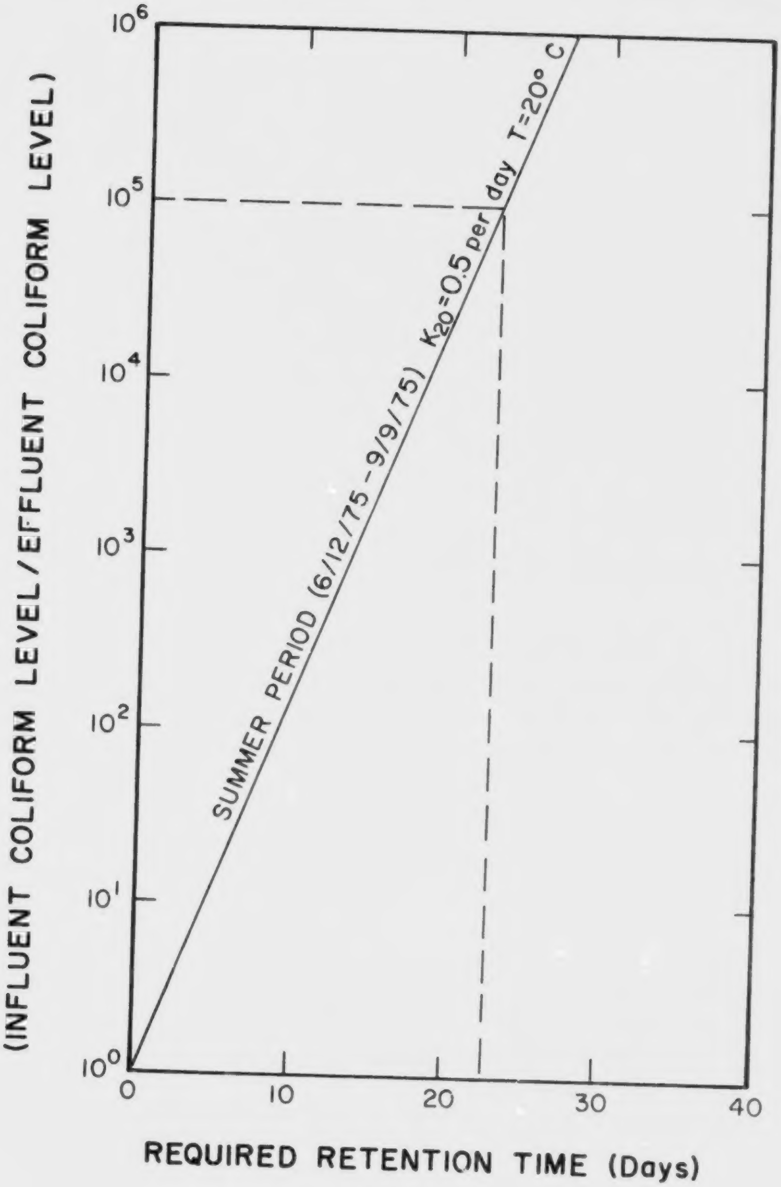


Figure 128. Retention time required in the Logan lagoon system to reduce an influent coliform level to a required effluent coliform level under summer conditions.

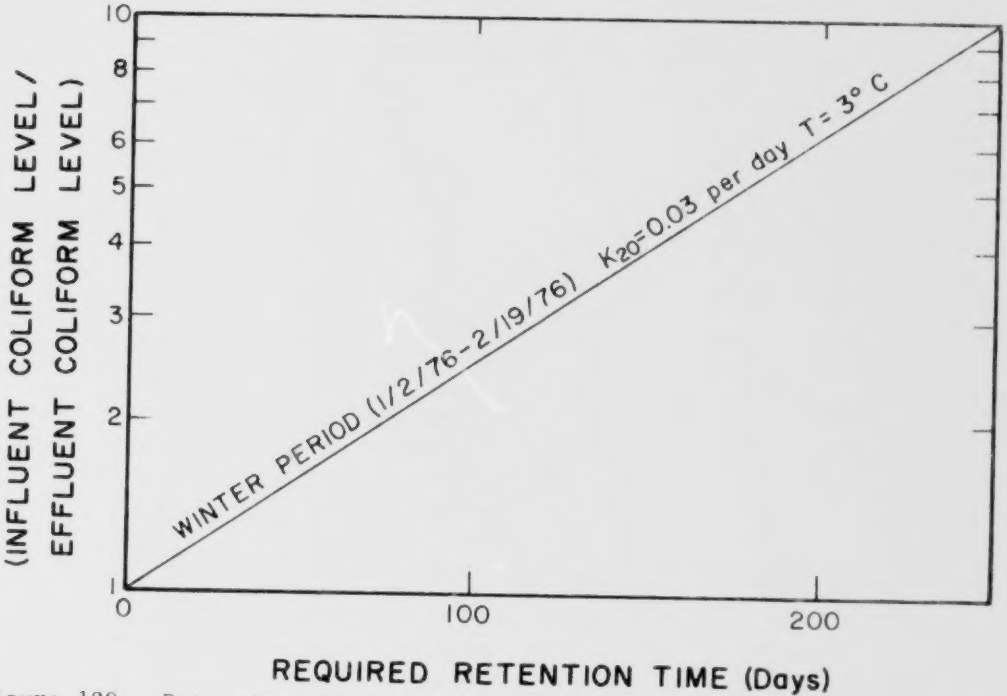


Figure 129. Retention time required in the Logan lagoon system to reduce an influent coliform level to a required effluent coliform level under winter conditions.

The results of the study indicated that the summer coliform decay rate coefficient, K_{20}, was equal to 0.50 per day and that the winter coliform decay rate coefficient, K_{20}, was equal to 0.03 per day. Thus, the rate of coliform die-away in the lagoon system was approximately 16 times greater during the summer period than during the winter period. Based on the results of this study, during the summer period it would take a hydraulic residence time of 23 days to reduce an influent coliform concentration of 10^7 organisms/100 ml to an effluent coliform concentration of 10^2 organisms/100 ml.

The greater coliform removal efficiency occurring during the summer period is due to a combination of several factors. Macko (1976) and Reynolds et al. (1976) have indicated that the amount of incident sunlight is a very significant factor in coliform die-away in lagoon systems.

The Logan lagoon system is covered over by ice during the winter period. This ice cover prevents sunlight penetration, which may account for the low coliform die-off rate during the winter period.

Data from the Logan lagoon system (Appendix E) indicated that the final effluent total coliform concentration (Station Number 9) exceeded 1000 organisms/100 ml 33.5 percent of the time based on MPN measurements and 13.1 percent of the time based on MF measurements. The final effluent fecal coliform concentration (Station Number 9) exceeded 200 organisms/100 ml 17.8 percent of the time based on MPN measurements and 10.3 percent of the time based on MF measurements.

SECTION 8

COMPARISON OF MPN AND MF COLIFORM CONCENTRATIONS IN LAGOON EFFLUENT

GENERAL

It is well established that comparison of absolute numbers of coliforms in a sample as determined by the MPN or MF technique should be based on the completed MF and the completed MPN procedure. Many operating personnel and regulatory agencies continue to employ the confirmed test for the MPN as a means of comparison with the MF results. Therefore, a careful evaluation of the confirmed and MF procedures for total and fecal coliforms is needed if the results of the two tests are to be interpreted correctly. Many comparisons of the MPN and MF techniques have been made for potable waters, lakes, rivers, various types of wastewater treatment plant effluents, and a very limited comparison has been made for wastewater stabilization lagoon effluents. To provide a better comparison of the two techniques for wastewater stabilization lagoons, a 15 month study was conducted at the Logan, Utah, wastewater stabilization lagoon.

The objectives of the study were to determine if the results of enumerating coliform bacteria in a waste stabilization pond system using the most probable number (MPN) technique are significantly different from results obtained using the membrane filter (MF) technique and to determine the relationship between results obtained employing the two different techniques. The analysis was performed on the lagoon performance data presented in Appendix E, Table E-1, and Figures E-1 through E-31. The location of each sample point is illustrated in Figure 12 and described in Table 3 of Section 4.

PREVIOUS STUDIES

Since the introduction of the membrane filter (MF) technique to the USA (Goetz, 1953), many comparisons of the results of MF and most probable number (MPN) bacteriological analyses of water and wastewater have been made (Kabler, 1954; Thomas and Woodward, 1956; Thomas et al., 1956; ORSANCO, 1959; Streeter and Robertson, 1960; Hoffman et al., 1964; Henderson, 1959; Benedict, 1961; McCarthy et al., 1958, 1961; McKee and McLaughlin, 1958; McKee et al., 1958; Mallman and Peabody, 1961). Considerable discussion of the merits and disadvantages of the two tests have been presented and as techniques continue to improve comparisons continue to appear (Green et al., 1975; Moran and Witter, 1976; Peterson, 1974; Presswood and Brown, 1973; Rose et al., 1975; Schaeffer et al., 1974; Geldreich et al., 1965). Many of these comparisons are made employing the results of the MF technique with the confirmed portion of the multiple tube technique. As pointed out by Geldreich (1972 and 1975) and many other investigators, this is not a valid comparison for actual numbers of coliform organisms. The completed MF technique should be compared only with the completed dilution tube procedure. Several examples of confirmed-completed MPN results can be found in the literature (Geldreich et al., 1962 and 1965). The results of these studies demonstrate that a significant difference in coliform numbers can occur between these two MPN procedures. The variables accounting for these differences are bacterial flora found in a given water, sample age, suppression of the non-coliform organisms by brilliant green dye and bile salts used in the confirmatory medium, among others.

Considerable variation in the results obtained with the MF technique when applied to chlorinated samples of wastewaters has been reported (Lin, 1973; Mowat, 1976; McKee et al., 1958). However, corrections in the procedure have overcome this difficulty, and Geldreich (1975) has discussed the limitations of the MF technique and modifications to be employed with chlorinated effluent samples.

When the limitations of the two procedures are considered, it is not difficult to understand why direct comparison of numerical values is difficult. There is little reason to place a great deal of significance on the actual values reported by either technique. Thomas (1955), Thomas et al. (1956), Thomas and Woodward (1956), and Laubusch (1958), among others, have pointed out that there is no reason to treat the results of the MPN procedure as absolute. Both the MF and MPN techniques are capable of giving results which can be used to determine the quality of a potable or treated wastewater effluent.

TOTAL COLIFORM REGRESSION ANALYSES

Various relationships between total coliform concentrations determined by the MPN and MF techniques were evaluated, and it was found that log-log relationships produced the best fit for the data as shown in Figure 130. Because a zero value does not exist in bacteriological analyses and the log of zero is undefined, all analyses reported as less than a given concentration were excluded from the log analyses. Figure 130 shows these log-log relationships, the equations of the lines of best fit, and the correlation coefficients. A highly significant (0.1 percent significance level) relationship exists between the total coliform concentrations determined by the two techniques. Better agreement between the two techniques was obtained at coliform concentrations greater than 10^3 coliforms per 100 ml (Figure 130).

High concentrations of algae or other solids could interfere with the MF technique. To determine if variations in solids concentrations contributed to the lack of agreement between the two techniques at lower coliform concentrations, the data were sorted by month and analyzed using a log-log relationship. The characteristics of the regression lines obtained are summarized in Table 13. Suspended solids data are available only for Sampling Stations 1 and 9 (see Figure 12, Table 3, and Figure E-4). The larger the deviation of the slope of the regression line from a value of 1, the greater the difference between the results of the two techniques. A comparison of the suspended solids concentrations and the months when the deviation of the slopes of the lines from a value of 1 were greatest indicates no relationship between

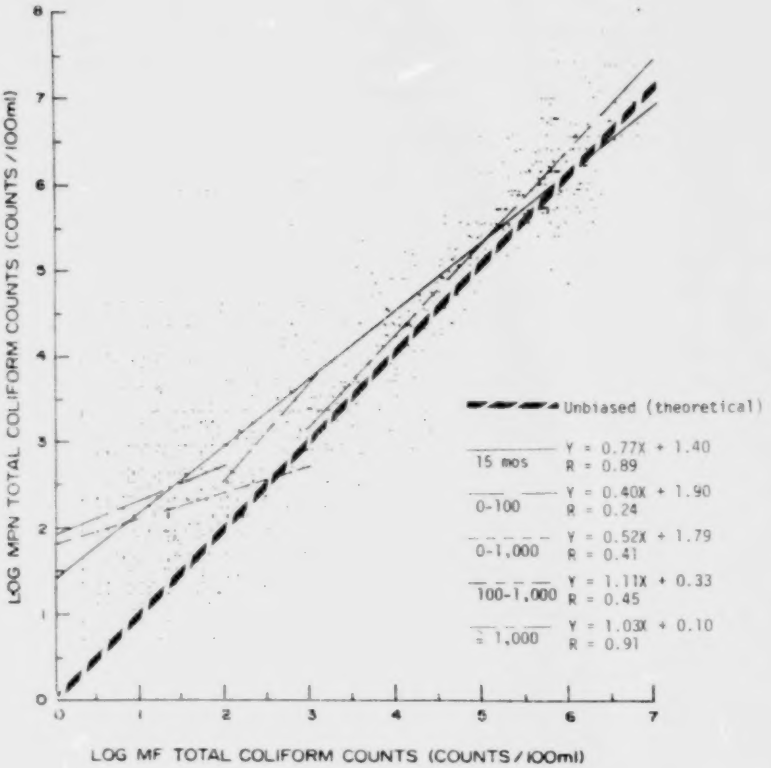


Figure 130. The relationship between the log of the total coliform concentrations determined by the MPN technique and the log of the total coliform concentrations determined by the MF technique.

suspended solids concentrations and the MPN and MF tests. The lower regression coefficient (slope of the line) between the MPN and MF techniques occurred during July and August of 1975 (see Table 13). However, these two months were also identified as having very low suspended solids concentrations (see Figure E-4, Appendix E).

Because of the wide variation in the relationship between the log of the MPN total coliform concentrations and the log of the MF total coliform concentrations at concentrations less than 1000 counts per 100 ml, a series of plots were prepared utilizing ranges of MF values varying from 0 to 100, 0 to 1,000, 100 to 1,000, and ≧ 1,000. The lines of best-fit for these ranges of values are shown in Figure 130. The characteristics of the regression lines for the relationships between the total coliform concentrations are summarized in Table 14. The slope of the line of best-fit for the ranges of MF values from 0 to 100 and 0 to 1,000 are significantly different (1% level) than the slope obtained with a fit of all (15 months) data (Snedecor, 1956). However, the intercepts of the lines of best-fit changed proportionately, and the predicted lower concentrations obtained with the equations of the line of best-fit for the MF concentrations of less than 1,000 counts per 100 ml do not differ significantly from the values obtained with the fit of all the data or at MF

TABLE 13. CHARACTERISTICS OF THE REGRESSION LINE FOR THE RELATIONSHIP BETWEEN THE TOTAL COLIFORM CONCENTRATIONS DETERMINED BY THE MOST PROBABLE NUMBER (MPN) (ORDINATE) AND THE MEMBRANE FILTER (MF) (ABSCISSA) TECHNIQUES

Month & Year	Number in Each Analysis	Intercept	Slope of the Line	Correlation Coefficient	Significance Level
6-75	43	1.68	0.65	0.84	1
7-75	67	2.27	0.58	0.75	1
8-75	50	2.70	0.47	0.68	1
9-75	57	1.92	0.67	0.82	1
10-75	63	1.43	0.80	0.87	1
11-75	54	1.05	0.83	0.93	1
12-75	47	1.19	0.89	0.94	1
1-76	45	1.28	0.91	0.96	1
2-76	56	0.73	0.93	0.98	1
3-76	75	1.00	0.87	0.81	1
4-76	80	0.21	0.94	0.93	1
5-76	70	0.98	0.83	0.93	1
6-76	60	0.38	1.02	0.96	1
7-76	51	0.92	0.86	0.87	1
8-76	55	1.76	0.65	0.83	1
All Data (15 Months)	873	1.40	0.77	0.89	1

TABLE 14. CHARACTERISTICS OF THE REGRESSION LINES FOR THE RELATIONSHIP BETWEEN THE TOTAL COLIFORM CONCENTRATIONS DETERMINED BY THE MOST PROBABLE NUMBER (MPN) AND THE MEMBRANE FILTER (MF) TECHNIQUES WITH THE DATA DIVIDED INTO RANGES OF VALUES

Range of MF Values Analyzed	Number of Analyses	Intercept[a]	Slope of the Line	Correlation Coefficient	Significance Level %	Residual Mean Square
0-100	390	1.90	0.40	0.24[b]	1	0.86
0-1000	501	1.79	0.52	0.42[b]	1	0.80
100-1000	127	0.33	1.11	0.45[b]	1	0.55
≧ 1000	375	0.10	1.03	0.91[b]	1	0.24
All Data (15 Months)	873[c]	1.40	0.77	0.89[b]	1	0.62

[a] When slopes differ, a comparison of intercept has no meaning.

[b] Slope differs at the 5% significance level from the slope of the line of best fit for all data (15 months).

[c] Number of analyses do not add due to inclusive end points. Excluding end points did not vary results of regression analyses.

concentrations of 100 counts per 100 ml or less. Correlation coefficients for the 0 to 100 and 0 to 1,000 range of MF values were much lower than the value obtained for the fit of all of the data; however, the correlation coefficients were still significant at the 1% level principally because of the large number of data points involved in the analysis. A comparison of intercepts is meaningless if the slopes differ; therefore, levels of significance are not shown in Table 14.

The least square fit of the data in the lower ranges leads to a questionable relationship and the equations should not be used to predict concentrations of total coliforms when measurements by either the MPN or MF techniques are available. Because of the positive bias of the fit of all data (Figure 130), this relationship is also questionable although statistically the prediction equation based upon all the data is indicated to be more reliable and has less positive bias than that exhibited by the fits of the lower ranges of values.

Theoretically the line of best-fit for the relationship between the results obtained with the two techniques of determining total coliform concentrations should have an intercept of 0. As illustrated in Table 14 there was a significant deviation from a zero intercept. To determine if a valid relationship could be obtained by forcing the line of best-fit through 0, a series of regression analyses were completed for the same range of MF values utilized in Table 14. The results of these analyses are summarized in Table 15. Correlation coefficients are not shown in Table 15 for the forced zero fit relationships because very little significance can be attached to correlation coefficients when forced 0 intercept analysis is employed. Residual mean square values for the least squares fit and the forced intercept fit can be compared to determine if the relationship is improved by employing a forced zero intercept analysis. Comparing the residual mean square values for the least squares fit for the range of MF values varying from 0 to 100, from 0 to 1000 and for all 15 months of data in Table 14 with values for the forced zero fit shown in Table 15. the intercept least-squares fit for the lower range comparisons contains approximately one-half the error associated with the zero intercept fit. Therefore, the equations obtained with the intercept fit is superior and would yield more reliable predicted values. The analyses of the MF values lying between 100 and 1000 and ≧ 1000 showed that the forced zero fit and the intercept least-squares fit residual mean square values are approximately equal. Therefore, the fit of the data at total coliform concentrations within these ranges is approximately equal with or without an intercept value.

Utilizing the equations of the lines of best-fit for the lower ranges (0-100 and 0-1000) of MF values and the line of best-fit for the total of 15 months of data to calculate predicted values, a comparison of total coliform concentrations determined by the MF and MPN techniques is presented in Table 16. Although the predicted values differ considerably, in all cases higher concentrations of total coliforms are predicted for the MPN technique. Thomas (1955) has shown that the MPN is inherently biased on the positive side and that the common 5-5-5 tube MPN test yields results that average 18% above the "true" coliform population. An examination of the data according to sampling station and month of the year shows that both the MPN and MF techniques measure the same trends; however, considerable differences exist between the numbers of organisms measured by the two techniques (see Table 14).

TABLE 15. CHARACTERISTICS OF THE REGRESSION LINES (FORCED ZERO INTERCEPT) FOR THE RELATIONSHIP BETWEEN THE TOTAL COLIFORM CONCENTRATIONS DETERMINED BY THE MOST PROBABLE NUMBER (MPN) AND THE MEMBRANE FILTER (MF) TECHNIQUES WITH THE DATA DIVIDED INTO RANGES OF VALUES

Range of MF Values Analyzed	Number of Analyses	Intercept	Slope of the Line	Correlation Coefficient	Residual Mean Square
0-100	391	0	1.75	*	1.57
0-1000	502	0	1.48	*	1.53
100-1000	128	0	1.24	*	0.54
≧ 1000	376	0	1.05	*	0.24
All Data (15 Months)	874	0	1.10	*	1.23

*Little significance can be attached to correlation coefficients when forced zero intercept analysis is employed. Must compare residual (error) mean square values for intercept fit and forced zero intercept fit.

[a] Number of analyses do not add due to inclusive end points. Excluding end points did not vary results of regression analyses.

TABLE 16. EQUIVALENT VALUES FOR MPN AND MF TOTAL COLIFORM CONCENTRATIONS CALCULATED FROM REGRESSION EQUATIONS

Range of MF Values Used To Determine Regression Equations[a]	Equivalent MPN Value, Counts/100 ml			
	Given MF Value, Counts/100 ml			
	10	100	500	1,000
Intercept Employed				
0 - 100	200	500	-	-
0 - 1000	204	676	1,560	2,240
All Data (15 months)	148	871	3,010	5,130
Forced Zero Intercept				
0 - 100	56	3,160	-	-
0 - 1000	30	912	9,870	27,500
All Data (15 months)	13	158	931	2,000

[a] See Tables 14 and 15 for equations used to calculate equivalent values.

There are many reasons why discrepancies between the two techniques exist; i.e., difficulty in counting the coliform organisms on the surface of the membrane filter, interference of solids, interference of other colonies, differences in media base, culturing conditions, filter manufacturing techniques, the statistical base for the MPN technique, etc. Based upon the results of this study, it appears reasonable to assume that at MF coliform concentrations of less than 1000 counts per 100 ml, the two techniques measure different populations. Similar results have been reported by Geldreich et al. (1962) and Geldreich (1972 and 1975) among others.

TOTAL COLIFORM GEOMETRIC MEAN COMPARISONS

To determine the amount of difference between actual values measured by each technique, the geometric mean monthly concentrations of total coliform bacteria by sampling station were analyzed by the standard t-test to determine if the log of the concentrations measured by both techniques differed (Snedecor, 1956). The results of these analyses are summarized in Table 17. An "X" in a significance level column indicates that the results obtained with both techniques do not differ at that level. The lower the percentage significance level, the greater the probability that there is no difference between the two means. For example, if the log of the geometric means of the total coliform concentrations measured by both techniques employed at Station 1 during June, 1975, lie between the interval of 5.4886 to 6.6738 there is no significant difference between the two values at the 10 percent level. The acceptable interval at the 1 percent level is 4.8954 to 7.2670. Standard confidence limits calculations are used to determine the intervals.

At Sampling Station 1 (raw sewage) the MPN and MF values for the total coliform concentrations were in agreement at all three levels of significance for ten months out of the total of 15 months studied. There appeared to be no relationship between the season and the variation between the two techniques. Suspended solids concentrations at Station 1 varied widely, but the variation between the two techniques for measuring total coliform concentrations did not follow a similar pattern (see Figure 15).

At lower total coliform concentrations (i.e., Sampling Stations 4 to 9) the number of months during which the two techniques produced statistically similar results ranged from 7 months to 11 months. Agreement did not seem to follow any seasonal or other identifiable pattern. In general, there was agreement between the total coliform concentrations determined by the MPN and MF techniques 67% of the time. This suggests that direct comparison of bacterial concentrations determined by the two techniques may not be valid. However, both techniques appear to detect the same trends and relative concentrations of coliform bacteria. Solids concentrations in the samples may account for some of the differences detected between the techniques, but it does not appear that much of the variation can be attributed to solids interference on the surface of the MF filter.

Trends shown by both MPN and MF results are in excellent agreement, and it appears reasonable to accept the results of either technique to evaluate the performance of wastewater stabilization ponds. Cognizance of differences

TABLE 17. COMPARISON OF GEOMETRIC MEANS FOR TOTAL COLIFORM CONCENTRATIONS BY THE MOST PROBABLE NUMBER (MPN) AND MEMBRANE FILTER (MF) TECHNIQUES

Month & Year	Sampling[a] Station	Geometric Mean Total Coliform Counts/100 ml		Do Not Differ At The Significance Level, %		
		MPN	MF	10	5	1
6-75	1	1,190,000	1,220,000	X	X	X
	2	14,900	12,000	X	X	X
	3	2,380	70		X	X
	4	396	21		X	X
	5	90	13		X	X
	6	36	3			
	7	170	4			
	8	46	5		X	X
	9	17	2			X
7-75	1	1,330,000	1,600,000	X	X	X
	2	3,410	2,130	X	X	X
	3	7,650	6			
	4	201	15			
	5	4,520	13			
	6	218	15			
	7	678	11			
	8	516	6			
	9	967	9			
8-75	1	793,000	235,000	X	X	X
	2	2,030	847	X	X	X
	3	941	13			
	4	424	11			
	5	5,320	35			
	6	2,000	12			
	7	1,100	6			
	8	7,290	9			
	9	7,420	24			
9-75	1	619,000	186,000	X	X	X
	2	1,800	309			X
	3	20,800	547			
	4	218	23			
	5	426	46			
	6	784	32			
	7	151	16			X
	8	597	13			
	9	863	8			
10-75	1	1,750,000	526,000			X
	2	52,800	19,700	X	X	X
	3	17,700	1,980			X
	4	8,250	768			
	5	182	57		X	X
	6	1,410	31			

TABLE 17. CONTINUED

Month & Year	Sampling Station[a]	Geometric Mean Total Coliform Counts/100 ml		Do Not Differ At The Significance Level, %		
		MPN	MF	10	5	1
10-75 Continued	7	133	26		X	X
	8	155	7			
	9	366	11			
11-75	1	2,310,000	909,000	X	X	X
	2	50,800	39,600	X	X	X
	3	7,130	2,000	X	X	X
	4	969	904	X	X	X
	5	217	25		X	X
	6	302	46			
	7	99	18	X	X	X
	8	73	4			
	9	99	9			X
12-75	1	13,400,000	3,120,000			
	2	41,600	7,780			X
	3	6,920	928		X	X
	4	716	62		X	X
	5	445	25			X
	6	102	11			
	7	18	2	b	b	b
	8	28	1	b	b	b
	9	83	2	b	b	b
1-76	1	12,200,000	4,140,000		X	X
	2	2,300,000	579,000			
	3	412,000	41,300		X	X
	4	613,000	226,000	X	X	X
	5	2,490	162		X	X
	6	214	25		X	X
	7	52	7			X
	8	79	7		X	X
	9	22	2			
2-76	1	4,850,000	3,910,000	X	X	X
	2	1,700,000	749,000			X
	3	80,000	296,000			
	4	824,000	299,000			
	5	120,000	35,700			X
	6	131	24	X	X	X
	7	42	7	X	X	X
	8	42	4			X
	9	59	1			
3-76	1	2,160,000	1,700,000	X	X	X
	2	748,000	579,000	X	X	X
	3	1,110,000	370,000		X	X
	4	646,000	263,000			
	5	351,000	193,000	X	X	X
	6	265,000	160,000			X

TABLE 17. CONTINUED

Month & Year	Sampling Station[a]	Geometric Mean Total Coliform Counts/100 ml		Do Not Differ At The Significance Level, %		
		MPN	MF	10	5	1
3-76	7	147,000	72,400			X
Continued	8	62,300	38,900	X	X	X
	9	80,700	32,900			
4-76	1	974,000	1,270,000	X	X	X
	2	35,900	21,200	X	X	X
	3	33,500	27,600	X	X	X
	4	3,520	2,910	X	X	X
	5	1,390	2,230	X	X	X
	6	806	848	X	X	X
	7	373	526	X	X	X
	8	359	478	X	X	X
	9	418	442	X	X	X
5-76	1	1,760,000	1,080,000	X	X	X
	2	46,500	32,700	X	X	X
	3	4,220	2,270	X	X	X
	4	1,600	541		X	X
	5	109	59	X	X	X
	6	89	33			X
	7	70	8			
	8	90	7			X
	9	93	7			
6-76	1	4,180,000	846,000			
	2	12,200	7,540	X	X	X
	3	1,740	594		X	X
	4	73	67	X	X	X
	5	99	24		X	X
	6	57	27	X	X	X
	7	43	26	X	X	X
	8	22	6	b	b	b
	9	14	8	X	X	X
7-76	1	2,350,000	659,000			X
	2	4,390	2,610	X	X	X
	3	2,370	394		X	X
	4	146	45		X	X
	5	1,300	318	X	X	X
	6	313	114	X	X	X
	7	528	324	X	X	X
	8	845	250	X	X	X
	9	1,450	15			X
8-76	1	800,000	852,000	X	X	X
	2	2,780	946	X	X	X
	3	3,260	253			X
	4	311	78			X
	5	384	28			

TABLE 17. CONTINUED

Month & Year	Sampling Station[a]	Geometric Mean Total Coliform Counts/100 ml		Do Not Differ At The Significance Level, %		
		MPN	MF	10	5	1
8-76 Continued	6	3,100	55			
	7	207	9			
	8	401	7			
	9	671	68			X

[a] Sampling Station 1 = Raw Wastewater
Sampling Station 2 = Effluent from Cell A_2
Sampling Station 3 = Effluent from Cell A_1
Sampling Station 4 = Effluent from Cell B_2
Sampling Station 5 = Effluent from Cell B_1
Sampling Station 6 = Effluent from Cell C
Sampling Station 7 = Effluent from Cell D
Sampling Station 8 = Effluent from Cell E
Sampling Station 9 = Effluent from Chlorine Contact Tank (Chlorine was not added)

[b] Insufficient data to make comparison.

in organism concentrations obtained by the two techniques is necessary when interpreting results.

FECAL COLIFORM REGRESSION ANALYSES

A log-log relationship best describes the fecal coliform concentrations determined by the MPN and MF techniques. All results reported as less than a given concentration were again excluded. Figure 131 shows a plot of the relationships, the equations of the lines of best fit, and the correlation coefficients. The relationships are significant at the 0.1 percent level, and there are a relatively small number of points which deviate from the general trend of the data. There appears to be no significant difference in the relative (not absolute numerical values) concentrations determined by the two techniques. The fact that the slope of the line describing the relationship for all of the data collected during the study is 1.00 and the intercept is 0.46 indicates that slightly higher concentrations of fecal coliform bacteria are expected from the MPN technique.

Monthly data were plotted and analyzed to determine if seasonal variations in the fecal coliform counts were produced by the two techniques. The characteristics of the lines of best fit are summarized in Table 18. The lower correlation coefficients correspond with the slopes of the lines (regression

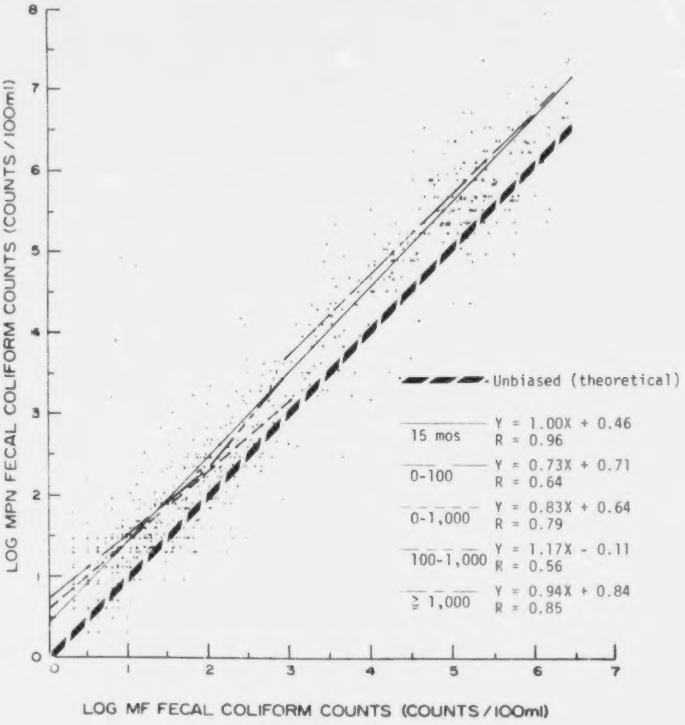


Figure 131. The relationship between the log of the fecal coliform concentrations determined by the MPN technique and the log of the fecal coliform concentrations determined by the MF technique.

coefficients) which deviate the most from a value of 1.0. These deviations occurred during August, 1975, and March, 1976. During these months, the suspended solids concentrations at Sampling Stations 1 and 9 did not differ significantly from previous or following months. Actually a reduction in suspended solids concentrations occurred in March, 1976, but the agreement between the results of the two techniques was poor. There appears to be no relationship between season or suspended solids concentrations and the variance between the fecal coliform counts determined by the two techniques. Based upon the relationship found for all of the fecal coliform bacteria data as well as the monthly regression analyses, it appears reasonable to assume that either technique will yield reliable estimates of the fecal coliform concentration. However, the absolute numerical values obtained from each technique may not agree.

Although the wide variation observed in the relationship between the logs of the MPN and MF total coliform concentrations at MF concentrations of less than 1000 counts per 100 ml were not observed for the fecal coliform measurements, regression analyses utilizing ranges of MF values varying from 0 to 100, 0 to 1000, 100 to 1000, and ≧ 1000 were also analyzed to determine if some obvious relationship had been overlooked. The lines of best-fit for these

TABLE 18. CHARACTERISTICS OF THE REGRESSION LINE FOR THE RELATIONSHIP BETWEEN THE FECAL COLIFORM CONCENTRATIONS DETERMINED BY THE MOST PROBABLE NUMBER (MPN) (ORDINATE) AND THE MEMBRANE FILTER (MF) (ABSCISSA) TECHNIQUES

Month & Year	Number in Each Analysis	Intercept	Slope of the Line	Correlation Coefficient	Significance Level, %
6-75	49	0.42	0.93	0.96	1
7-75	68	0.60	0.92	0.96	1
8-75	51	0.46	0.88	0.77	1
9-75	64	0.63	0.87	0.95	1
10-75	58	0.81	0.89	0.93	1
11-75	46	0.58	0.96	0.96	1
12-75	31	0.97	0.96	0.98	1
1-76	45	0.87	1.00	0.97	1
2-76	47	0.36	1.06	0.98	1
3-76	72	1.24	0.84	0.83	1
4-76	66	0.28	1.02	0.97	1
5-76	55	0.31	1.04	0.96	1
6-76	51	0.23	1.09	0.98	1
7-76	58	0.14	1.13	0.97	1
8-76	58	0.42	1.00	0.95	1
All Data (15 Months)	819	0.46	1.00	0.96	1

ranges of values are shown in Figure 131. The characteristics of the regression lines for the relationships between the fecal coliform concentrations are summarized in Table 19. The slopes of the lines of best-fit for the ranges of MF values from 100 to 1000 and ≧ 1000 counts per 100 ml do not differ statistically (5% level) from the slope of the line of best-fit for all of the data (15 months). The intercept of the line of best-fit for the range from 100 to 1000 counts per 100 ml differed (5% level) from the intercept of the line of best-fit for all data. As mentioned earlier, a comparison of intercepts is meaningless if the slopes differ; therefore, levels of significance are not indicated in Table 19 for intercepts except when the slopes are parallel. The slopes of the lines of best-fit for the ranges of MF values from 0 to 100 and 0 to 1000 counts per 100 ml differ statistically (5% level) from the slope of the line of best-fit for all of the data. Correlation coefficients for all of the regression analyses of the subdivisions of the data were less than the correlation coefficients obtained for the fit of all data collected over the 15 months of study. But all regression analyses were significant at the 1% level. A definite relationship appears to exist between the fecal coliform concentrations measured by the MPN and MF techniques. There is a positive bias in the relationship, but the bias is much less than that observed for the total coliform relationship.

TABLE 19. CHARACTERISTICS OF THE REGRESSION LINES FOR THE RELATIONSHIP BETWEEN THE FECAL COLIFORM CONCENTRATIONS DETERMINED BY THE MOST PROBABLE NUMBER (MPN) AND THE MEMBRANE FILTER (MF) TECHNIQUES WITH THE DATA DIVIDED INTO RANGES OF VALUES

Range of MF Values Analyzed	Number of Analyses	Intercept	Slope of the Line	Correlation Coefficient	Significance Level, %	Residual Mean Square
0-100	435	0.71	0.73[b]	0.64	1	0.25
0-1000	536	0.64	0.83[b]	0.79	1	0.26
100-1000	105	-0.11[a]	1.17	0.56	1	0.23
≥ 1000	284	0.84	0.94	0.85	1	0.25
All Data (15 Months)	819[c]	0.46	1.00	0.96	1	0.27

[a] Intercept differs at the 5% significance level from the intercept for all data (15 months). When slopes differ, a comparison of intercepts has no meaning.

[b] Slope differs at the 5% significance level from the slope of the line of best fit for all data (15 months).

[c] Number of analyses do not add due to inclusive end points. Excluding end points did not vary results of regression analyses.

Forced zero intercept regression analyses were also performed with the ranges of values reported in Table 19 even though the intercepts obtained with the fecal coliform concentrations analyses were smaller than those determined for the total coliforms. The results of these analyses are summarized in Table 20. As mentioned earlier, it is necessary to use residual mean squares to compare the intercept and the forced zero fits of the data. The residual (error) mean square values for the ranges of MF values between 0 to 100, 0 to 1000 and the fit of all 15 months of data were smaller with the intercept fit; however, at the higher concentration ranges of 100 to 1000 and equal to or greater than 1000 counts per 100 ml the two methods of analysis produced approximately equal statistical results. Improvement does not result from a forced zero intercept fit of the data, and the intercept fits of the data should yield more reliable estimates of fecal coliform concentrations.

Using the equations of the lines of best-fit for the lower ranges (0-100 and 0-1000) of MF concentrations and the line of best-fit for the total of 15 months of data to calculate predicted values, a comparison of fecal coliform concentrations determined by the MF and MPN techniques is presented in Table 21. The slopes of the regression equations differ statistically, and the numerical values calculated from the equations and presented in Table 21 show that the equations for the 0 to 100 and 0 to 1000 ranges produce better numerical agreement between the MF and MPN techniques. However, statistically the regression equation for all of the data should yield a more reliable estimate. There appears to be a definite relationship between the fecal

TABLE 20. CHARACTERISTICS OF THE REGRESSION LINES (FORCED ZERO INTERCEPT) FOR THE RELATIONSHIP BETWEEN THE FECAL COLIFORM CONCENTRATIONS DETERMINED BY THE MOST PROBABLE NUMBER (MPN) AND THE MEMBRANE FILTER (MF) TECHNIQUES WITH THE DATA DIVIDED INTO RANGES OF VALUES

Range of MF Values Analyzed	Number of Analyses	Intercept	Slope of the Line	Correlation Coefficient	Residual Mean Square
0-100	436	0	1.28	*	0.39
0-1000	537	0	1.20	*	0.37
100-1000	106	0	1.12	*	0.23
≧ 1000	285	0	1.11	*	0.27
All Data (15 months)	820[a]	0	1.12	*	0.35

*Little significance can be attached to correlation coefficients when forced zero intercept analysis is employed. Must compare residual (error) mean square values for intercept fit and forced zero intercept fit.

[a] Number of analyses do not add due to inclusive end points. Excluding end points did not vary results of regression analyses.

TABLE 21. EQUIVALENT VALUES FOR MPN AND MF FECAL COLIFORM CONCENTRATIONS CALCULATED FROM EQUATIONS

Range of MF Values Used To Determine Regression Equations[a]	Equivalent MPN Value, Counts/100 ml			
	Given MF Value, Counts/100 ml			
	10	100	500	1000
Intercept Employed				
0 - 100	28	148	-	-
0 - 1000	30	200	759	1350
All Data (15 months)	29	288	1440	2880
Forced Zero Intercept				
0 - 100	19	363	-	-
0 - 1000	16	251	1730	3980
All Data (15 months)	13	174	1050	2290

[a] See Tables 19 and 20 for equations used to calculate equivalent values.

coliform concentrations measured by the MPN and MF techniques, and it appears reasonable to assume that both techniques measure similar trends but do not necessarily result in the same bacterial concentrations.

FECAL COLIFORM GEOMETRIC MEAN COMPARISONS

The geometric mean monthly concentrations of fecal coliform by sampling station were compared using the standard t-test to determine if the log of the concentrations measured by both techniques differed. The results of these analyses are summarized in Table 22. As before an "X" in a column indicates that the monthly means obtained by both techniques do not differ at the designated significance level.

Monthly fecal coliform concentrations for the raw sewage (Station 1) were in agreement at all three levels of significance for only 5 months out of the total of 15 months. There appears to be no relationship between agreement and the seasons or suspended solids concentrations (compare Table 22 with Figure E-4). When high concentrations of fecal coliform occurred at other stations, a significant difference was detected in the means. At lower concentrations of fecal coliforms there was excellent agreement in the results obtained by the MPN and MF techniques.

Apparently variations between the results obtained with the MPN and MF techniques to determine fecal coliform concentrations can be attributed to inherent differences in techniques, and results from both techniques appear to be acceptable for identifying relative fecal coliform concentrations. However, the absolute numerical values obtained from the two techniques may not agree.

STANDARD DEVIATIONS

Using an F-test, the standard deviations from the log of the means for both techniques do not differ statistically at the 1% level of significance (Table 23), and one technique does not appear to be more reliable than the other. The same trends are indicated by the results obtained with both techniques (Table 23).

SUMMARY AND CONCLUSIONS

The inherent variations in the MPN and MF techniques for measuring total and fecal coliform bacteria appear to be equivalent, and thus one technique does not appear to be more reliable than the other.

Both techniques appear to show the same trends. Variations in results when analyzing a common sample appear to be equal for both the total and fecal MPN and the MF techniques (see Table 23). However, the absolute numerical value obtained from the two techniques may differ substantially.

TABLE 22. COMPARISON OF GEOMETRIC MEANS FOR FECAL COLIFORM CONCENTRATIONS DETERMINED BY THE MOST PROBABLE NUMBER (MPN) AND MEMBRANE FILTER (MF) TECHNIQUES

Month & Year	Sampling Station[a]	Geometric Mean Fecal Coliform Counts/100 ml		Do Not Differ At The Significance Level, %		
		MPN	MF	10	5	1
6-75	1	500,000	310,000	X	X	X
	2	4,420	1,660	X	X	X
	3	434	211	X	X	X
	4	59	31	X	X	X
	5	16	7	X	X	X
	6	14	7	X	X	X
	7	31	19	X	X	X
	8	5	3	X	X	X
	9	5	2		X	X
7-75	1	913,000	442,000	X	X	X
	2	930	289	X	X	X
	3	416	273	X	X	X
	4	33	12			X
	5	30	2			
	6	16	10	X	X	X
	7	31	8			
	8	4	1			
	9	5	3		X	X
8-75	1	298,000	8,400		X	X
	2	561	166			X
	3	234	118	X	X	X
	4	55	64	X	X	X
	5	52	37	X	X	X
	6	49	94	X	X	X
	7	37	61	X	X	X
	8	7	10	X	X	X
	9	10	7	X	X	X
9-75	1	202,000	155,000	X	X	X
	2	570	224	X	X	X
	3	520	176	X	X	X
	4	60	43	X	X	X
	5	48	15			X
	6	33	4			
	7	11	6	X	X	X
	8	11	8	X	X	X
	9	34	5			
10-75	1	285,000	87,600			X
	2	4,230	2,120	X	X	X
	3	1,760	239		X	X
	4	258	104	X	X	X
	5	68	15			X

TABLE 22. CONTINUED

Month & Year	Sampling[a] Station	Geometric Mean Fecal Coliform Counts/100 ml		Do Not Differ At The Significance Level, %		
		MPN	MF	10	5	1
10-75 Continued	6	77	8			X
	7	22	7		X	X
	8	9	3		X	X
	9	30	2			
11-75	1	736,000	146,000			X
	2	26,000	4,110			X
	3	775	73	X	X	X
	4	127	160	X	X	X
	5	59	17	X	X	X
	6	37	12	X	X	X
	7	19	8	X	X	X
	8	5	2			X
	9	13	2			
12-75	1	1,720,000	407,000		X	X
	2	14,000	263			
	3	1,400	115			X
	4	120	28	X	X	X
	5	18	3			
	6	24	3			X
	7	6	2	b	b	b
	8	6	1	b	b	b
	9	17	0	b	b	b
1-76	1	5,960,000	1,290,000			X
	2	983,000	187,000			
	3	107,000	13,400	X	X	X
	4	355,010	70,600			X
	5	649	39	X	X	X
	6	101	16	X	X	X
	7	9	2		X	X
	8	44	5			X
	9	11	2			X
2-76	1	3,290,000	1,240,000			
	2	813,000	196,000			
	3	313,000	71,500			
	4	616,000	66,600			
	5	63,700	6,550			
	6	100	7	X	X	X
	7	386	3		X	X
	8	14	4	X	X	X
	9	71	2	X	X	X
3-76	1	1,110,000	572,000	X	X	X
	2	209,000	89,200	X	X	X
	3	390,000	81,300			X
	4	235,000	68,400			X

TABLE 22. CONTINUED

Month & Year	Sampling Station[a]	Geometric Mean Fecal Coliform Counts/100 ml		Do Not Differ At The Significance Level, %		
		MPN	MF	10	5	1
3-76 Continued	5	189,000	60,900			
	6	184,000	45,500			
	7	62,100	25,400			X
	8	40,700	14,800			
	9	27,000	17,100	X	X	X
4-76	1	768,000	474,000	X	X	X
	2	6,570	2,980	X	X	X
	3	6,550	3,260	X	X	X
	4	493	394	X	X	X
	5	253	77	X	X	X
	6	178	70	X	X	X
	7	102	24	X	X	X
	8	101	33	X	X	X
	9	112	34	X	X	X
5-76	1	1,010,000	193,000			X
	2	5,820	3,620	X	X	X
	3	1,278	212	X	X	X
	4	93	61	X	X	X
	5	7	2			X
	6	15	7	X	X	X
	7	18	6	X	X	X
	8	7	3		X	X
	9	6	4	X	X	X
6-76	1	1,320,000	185,000			
	2	2,330	1,170	X	X	X
	3	100	36	X	X	X
	4	10	5	X	X	X
	5	5	3	X	X	X
	6	15	2	X	X	X
	7	4	2	X	X	X
	8	3	1	b	b	b
	9	4	3	X	X	X
7-76	1	830,000	127,000			
	2	664	192	X	X	X
	3	145	36	X	X	X
	4	19	15	X	X	X
	5	61	26	X	X	X
	6	52	12	X	X	X
	7	23	16	X	X	X
	8	42	10	X	X	X
	9	96	10			X
8-76	1	228,000	512,000			X
	2	301	71	X	X	X
	3	122	61	X	X	X

TABLE 22. CONTINUED

Month & Year	Sampling Station[a]	Geometric Mean Fecal Coliform Counts/100 ml		Do Not Differ At The Significance Level, %		
		MPN	MF	10	5	1
8-76 Continued	4	49	19			
	5	20	8	X	X	X
	6	40	23	X	X	X
	7	19	7	X	X	X
	8	7	3	X	X	X
	9	11	4			X

[a] Sampling Station 1 = Raw Wastewater
Sampling Station 2 = Effluent from Cell A_2
Sampling Station 3 = Effluent from Cell A_1
Sampling Station 4 = Effluent from Cell B_2
Sampling Station 5 = Effluent from Cell B_1
Sampling Station 6 = Effluent from Cell C
Sampling Station 7 = Effluent from Cell D
Sampling Station 8 = Effluent from Cell E
Sampling Station 9 = Effluent from Chlorine Contact Tank (chlorine was not added)

[b] Insufficient data to make comparison.

TABLE 23. THE MEANS AND STANDARD DEVIATIONS FOR THE LOG VALUES OF THE TOTAL AND FECAL COLIFORM CONCENTRATIONS AT THE VARIOUS SAMPLING STATIONS

Sampling Station	MPN Total Coliform		MF Total Coliform		MPN Fecal Coliform		MF Fecal Coliform	
	Log Mean	Standard Deviation of the Sample	Log Mean	Standard Deviation of the Sample	Log Mean	Standard Deviation of the Sample	Log Mean	Standard Deviation of the Sample
1	6.33	0.61	6.01	0.68	5.92	0.64	5.38	0.78
2	4.50	1.14	4.16	1.11	3.85	1.26	3.35	1.21
3	4.20	1.22	3.32	1.51	3.29	1.38	2.76	1.31
4	3.38	1.49	2.79	1.61	2.61	1.66	2.23	1.44
5	3.13	1.31	2.30	1.43	2.14	1.47	1.55	1.45
6	2.72	1.21	1.83	1.24	1.92	1.35	1.36	1.19
7	2.40	1.23	1.53	1.28	1.66	1.23	1.15	1.13
8	2.45	1.21	1.46	1.33	1.40	1.30	0.96	1.19
9	2.53	1.24	1.50	1.43	1.52	1.20	0.91	1.19

Seasonal variations and suspended solids concentrations do not appear to account for the differences in absolute numerical values obtained by the MPN and MF techniques. Large variations due to inherent differences between the two techniques could account for much of this difference.

SECTION 9

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APPENDIX A

CHLORINATION FIELD DATA
AUGUST 1, 1975 - AUGUST 24, 1976

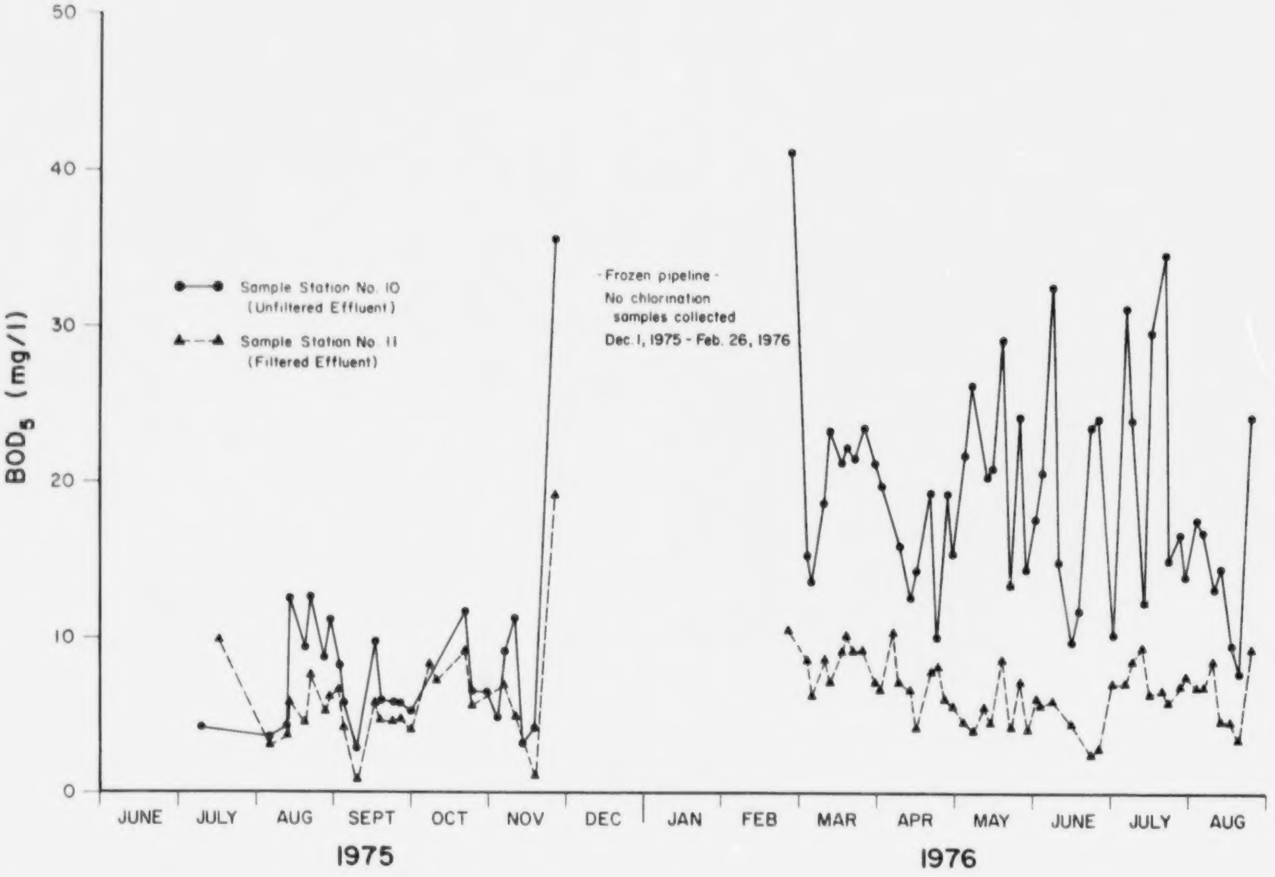

Figure A-1. Seasonal biochemical oxygen demand for unfiltered and filtered lagoon effluent (Sample Nos. 10 and 11.

TABLE A-1. CHLORINATION FIELD DATA COLLECTED FROM AUGUST 1, 1976 TO AUGUST 24, 1976.

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
8	6	75	10	24000.	30.	45.06	38.49	4.89	0.00	7.86	5.77	8.0	8.09	22.0	3.8	0.00	0.00	0.00
8	6	75	11	2400.	4.	59.38	14.96	1.59	0.00	4.54	2.99	2.3	7.80	22.0	5.2	0.00	0.00	0.00
8	6	75	12	28.	0.	******	30.00	4.02	0.00	5.69	3.57	6.2	8.00	22.0	4.8	13.60	10.00	0.00
8	6	75	13	0.	0.	******	30.00	5.16	0.00	5.40	3.56	6.6	8.00	22.0	4.8	13.60	9.20	0.00
8	6	75	14	0.	0.	44.00	1.00	4.35	0.00	5.29	3.71	6.5	8.10	22.0	4.6	13.60	8.80	0.00
8	6	75	15	4.	0.	******	31.00	3.98	0.00	5.71	3.65	7.4	8.06	22.0	4.1	9.07	7.90	0.00
8	6	75	16	0.	0.	******	24.00	4.20	0.00	5.31	3.17	7.2	8.05	22.0	4.7	9.07	7.60	0.00
8	6	75	17	0.	0.	36.00	32.50	4.15	0.00	4.90	3.34	7.2	8.10	22.0	4.7	9.07	7.40	0.00
8	6	75	18	430.	0.	******	7.50	5.24	0.00	6.57	3.97	7.8	8.03	22.0	4.7	4.58	4.55	0.00
8	6	75	19	930.	0.	******	32.00	3.66	0.00	6.03	3.49	7.4	8.10	22.0	4.7	4.58	4.30	0.00
8	6	75	20	930.	0.	34.00	26.00	4.80	0.00	5.91	3.49	7.0	8.00	22.0	4.7	4.58	4.05	0.00
8	11	75	10	4600.	30.	******	******	*****	0.00	24.91	22.06	19.0	8.58	22.5	11.1	0.00	0.00	0.00
8	11	75	11	430.	3.	21.34	******	*****	0.00	1.20	2.06	0.8	7.92	21.5	20.0	0.00	0.00	0.00
8	11	75	12	2400.	4.	******	******	*****	0.00	19.69	16.26	15.0	8.45	21.5	9.3	4.58	1.75	0.00
8	11	75	13	75.	0.	******	******	*****	0.00	19.23	17.54	19.0	8.48	22.5	9.1	4.58	1.15	0.00
8	11	75	14	70.	0.	******	******	*****	0.00	18.06	14.94	20.0	8.49	22.5	9.0	4.58	1.15	0.00
8	11	75	15	4.	0.	******	******	*****	0.00	16.77	15.26	21.0	8.46	22.5	9.2	9.07	8.10	0.00
8	11	75	16	0.	0.	******	5.00	*****	0.00	16.16	14.44	22.0	8.47	22.5	8.9	9.07	7.30	0.00
8	11	75	17	0.	0.	******	5.00	*****	0.00	11.46	14.60	25.0	8.48	22.5	8.8	9.07	7.70	0.00
8	11	75	18	0.	0.	******	5.00	*****	0.00	16.24	15.40	23.0	8.40	22.5	8.9	13.06	12.40	0.00
8	11	75	19	0.	0.	******	5.00	*****	0.00	15.24	14.16	26.0	8.40	22.5	8.7	13.06	12.88	0.00
8	11	75	20	0.	0.	******	******	*****	0.00	16.28	15.60	26.0	8.40	22.5	8.6	13.06	11.80	0.00
8	13	75	10	1500.	90.	******	48.53	3.32	0.00	21.92	16.80	21.0	8.60	21.5	8.5	0.00	0.00	0.00
8	13	75	11	4600.	0.	29.46	36.74	0.14	0.00	2.77	2.26	2.9	8.06	22.0	3.9	0.00	0.00	0.00
8	13	75	12	0.	0.	******	29.50	3.22	0.00	18.06	13.46	26.0	8.19	22.0	6.5	15.88	10.70	0.00
8	13	75	13	0.	0.	******	35.00	3.01	0.00	17.23	12.86	25.5	8.45	22.0	6.6	15.88	10.20	0.00
8	13	75	14	0.	0.	59.00	36.00	3.52	0.00	17.94	13.29	25.5	8.58	22.0	6.9	15.88	9.70	0.00
8	13	75	15	0.	40.	******	51.00	2.55	0.00	18.86	13.91	24.0	8.59	22.0	7.7	11.35	10.00	0.00
8	13	75	16	4.	0.	******	43.50	2.24	0.00	17.57	13.11	24.0	8.52	22.0	7.4	11.35	9.80	0.00
8	13	75	17	4.	0.	55.00	40.00	1.92	0.00	17.09	12.91	25.0	8.63	22.0	6.5	11.35	9.50	0.00
8	13	75	18	0.	0.	******	42.00	2.94	0.00	18.71	12.94	23.0	8.58	22.0	7.5	6.81	6.65	0.00
8	13	75	19	0.	0.	******	30.00	3.67	0.00	17.83	12.91	23.0	8.58	22.0	7.6	6.81	6.40	0.00
8	13	75	20	0.	0.	55.00	42.00	1.99	0.00	17.89	13.20	25.0	8.62	22.0	7.5	6.81	6.30	0.00
8	19	75	10	750.	40.	81.17	24.76	0.32	0.00	40.09	29.82	32.0	9.22	20.0	9.6	0.00	0.00	0.00
8	19	75	11	11000.	7.	28.47	17.88	1.96	0.00	6.56	3.94	7.1	8.60	20.5	5.1	0.00	0.00	0.00
8	19	75	12	20.	0.	******	28.50	0.61	0.00	34.04	25.19	35.0	9.05	20.0	7.6	6.00	2.31	0.00
8	19	75	13	4.	0.	******	******	1.03	0.00	40.90	31.00	32.0	9.05	20.0	7.6	6.00	2.20	0.00
8	19	75	14	4.	0.	65.00	34.50	2.17	0.00	32.80	25.32	36.0	9.00	20.0	7.6	6.00	2.05	0.00
8	19	75	15	0.	0.	******	29.50	2.85	0.00	32.49	25.00	43.0	8.54	20.0	7.6	20.00	5.60	1.80
8	19	75	16	0.	0.	******	40.50	0.19	0.00	30.74	25.17	41.0	8.50	20.0	7.6	20.00	4.80	1.12
8	19	75	17	0.	0.	56.50	50.00	1.29	0.00	29.06	27.49	40.0	8.50	20.0	7.6	20.00	4.00	0.68
8	19	75	21	75.	0.	******	28.50	1.54	0.00	7.17	5.03	7.7	8.30	20.5	10.0	10.00	2.45	0.00
8	19	75	22	9.	0.	******	36.00	1.71	0.00	7.31	4.40	7.5	8.25	20.5	10.0	10.00	2.30	0.00
8	19	75	23	9.	0.	41.00	49.00	1.96	0.00	7.49	4.77	6.7	8.31	20.5	10.0	10.00	2.10	0.00
8	21	75	10	430.	40.	******	128.79	*****	0.00	62.70	59.30	44.5	9.37	20.0	14.9	0.00	0.00	0.00
8	21	75	11	2400.	0.	14.95	******	*****	0.00	15.66	12.63	15.5	8.76	20.0	6.1	0.00	0.00	0.00
8	21	75	12	93.	0.	******	5.00	*****	0.00	49.68	42.88	54.0	9.13	20.0	9.0	4.00	1.45	0.00
8	21	75	13	23.	0.	******	4.00	*****	0.00	46.10	44.90	56.0	9.10	20.0	9.4	4.00	1.50	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
8	21	75	14	23.	0.	56.00	5.00	*****	0.00	49.78	47.67	59.0	9.10	20.0	9.5	4.00	1.20	0.00
8	21	75	15	0.	0.	******	5.00	*****	0.00	40.83	37.67	52.0	9.90	20.0	9.7	12.00	5.30	1.40
8	21	75	16	4.	0.	******	3.00	*****	0.00	41.30	37.35	54.0	8.90	20.0	9.7	12.00	3.60	1.30
8	21	75	17	9.	0.	56.00	6.50	*****	0.00	37.20	30.40	55.0	8.85	20.0	9.3	12.00	3.00	0.60
8	21	75	18	4.	0.	******	7.00	*****	0.00	40.40	39.30	46.0	8.64	20.0	9.2	29.76	14.00	3.90
8	21	75	19	0.	0.	******	11.50	*****	0.00	35.60	32.07	48.0	8.63	20.0	9.2	29.76	11.20	4.30
8	21	75	20	0.	0.	47.00	11.50	*****	0.00	49.80	32.20	43.0	8.61	20.0	9.8	29.76	9.40	2.70
8	21	75	21	0.	0.	******	5.00	*****	0.00	16.67	11.53	14.0	8.42	20.0	5.2	8.00	1.85	0.10
8	21	75	22	0.	0.	******	5.00	*****	0.00	21.40	13.65	14.0	8.42	20.0	5.3	8.00	1.55	0.00
8	21	75	23	0.	0.	******	5.00	*****	0.00	13.11	4.51	14.0	8.42	20.0	6.1	8.00	1.50	0.00
8	26	75	10	280.	40.	111.94	29.50	0.40	0.00	33.50	29.80	****	9.49	19.5	10.0	0.00	0.00	0.00
8	26	75	11	300.	300.	133.26	******	0.66	0.00	11.30	6.43	10.5	8.89	20.0	10.5	0.00	0.00	0.00
8	26	75	12	53.	4.	******	30.00	0.42	0.00	29.40	25.87	32.0	9.23	19.5	10.5	2.00	0.55	0.00
8	26	75	13	1100.	4.	******	31.50	0.40	0.00	30.60	24.93	32.0	9.39	19.5	10.1	2.00	0.48	0.00
8	26	75	14	930.	15.	56.00	33.00	0.29	0.00	28.90	23.00	32.0	9.38	19.5	9.5	2.00	0.43	0.00
8	26	75	15	150.	0.	******	34.00	0.25	0.00	29.30	23.94	36.0	9.30	19.5	11.1	10.00	6.55	1.35
8	26	75	16	0.	0.	******	31.50	0.33	0.00	20.20	17.15	34.0	9.30	19.5	10.0	10.00	6.60	1.25
8	26	75	17	0.	0.	16.50	29.50	0.21	0.00	42.50	30.33	33.0	9.30	19.5	10.2	10.00	6.50	1.10
8	26	75	18	0.	0.	******	51.50	0.10	0.00	34.20	26.30	44.0	9.18	19.5	10.8	24.58	11.80	3.85
8	26	75	19	3.	0.	******	48.00	0.23	0.00	33.30	26.87	44.0	9.18	19.5	7.7	24.58	11.60	3.35
8	26	75	20	0.	0.	80.00	49.50	0.33	0.00	34.90	28.60	42.0	9.11	19.5	10.2	24.58	11.50	3.15
8	26	75	21	0.	0.	******	22.50	0.37	0.00	27.30	10.52	20.0	8.93	20.0	9.2	6.00	5.95	1.80
8	26	75	22	0.	0.	******	25.50	0.01	0.00	7.50	6.76	18.0	8.93	20.0	9.4	6.00	5.45	1.49
8	26	75	23	0.	0.	26.00	24.00	0.59	0.00	15.30	9.20	19.0	8.82	20.0	9.6	6.00	4.85	1.22
8	28	75	10	930.	30.	84.56	44.51	0.05	0.00	47.58	39.83	36.0	9.30	19.5	12.7	0.00	0.00	0.00
8	28	75	11	9300.	230.	42.48	36.01	0.11	0.00	18.68	9.80	18.0	9.00	18.5	7.9	0.00	0.00	0.00
8	28	75	12	240.	9.	******	76.00	0.03	0.00	42.80	36.00	40.0	9.27	19.5	10.5	1.00	0.28	0.00
8	28	75	13	150.	0.	******	44.00	0.05	0.00	34.37	30.74	42.0	9.30	19.5	10.4	1.00	0.20	0.00
8	28	75	14	40.	0.	162.00	37.50	0.07	0.00	41.90	37.50	41.0	9.32	19.5	10.3	1.00	0.15	0.00
8	28	75	15	0.	0.	******	56.00	0.09	0.00	40.07	32.07	51.0	9.25	19.5	10.3	8.00	4.85	1.05
8	28	75	16	0.	0.	******	37.50	0.15	0.00	37.69	32.69	51.0	9.20	19.5	10.2	8.00	4.00	0.81
8	28	75	17	0.	0.	66.00	35.00	0.05	0.00	40.00	33.08	51.0	9.20	19.5	10.3	8.00	3.35	0.48
8	28	75	18	0.	0.	******	37.50	0.12	0.00	38.80	32.13	50.0	9.14	19.5	10.1	19.66	2.95	2.95
8	28	75	19	0.	0.	******	37.50	0.12	0.00	38.40	30.67	51.0	9.08	19.5	10.0	19.66	0.32	0.32
8	28	75	20	0.	0.	67.00	39.50	0.05	0.00	35.60	31.04	50.0	9.09	19.5	10.0	19.66	0.00	0.00
8	28	75	21	0.	0.	******	62.00	0.12	0.00	19.10	9.17	21.0	8.98	18.5	7.5	4.00	2.08	0.34
8	28	75	22	0.	0.	******	32.00	0.12	0.00	18.00	8.91	19.0	8.99	18.5	7.5	4.00	1.70	0.19
8	28	75	23	0.	0.	39.50	35.00	0.11	0.00	19.54	8.57	22.0	9.00	18.5	7.5	4.00	1.33	0.10
9	2	75	10	110.	30.	61.51	40.02	0.04	0.00	33.10	27.00	25.0	9.25	18.0	8.6	0.00	0.00	0.00
9	2	75	11	9300.	40.	47.19	27.61	0.16	0.00	46.12	21.24	21.0	8.94	18.0	7.0	0.00	0.00	0.00
9	2	75	12	7.	0.	******	31.00	0.10	0.00	26.60	21.15	32.0	9.22	18.0	7.2	4.00	1.45	0.20
9	2	75	13	0.	0.	******	33.50	0.09	0.00	23.43	20.29	32.0	9.25	18.0	7.4	4.00	1.20	0.10
9	2	75	14	0.	0.	66.00	47.00	0.10	0.00	25.45	19.55	32.0	9.26	18.0	7.3	4.00	0.85	0.00
9	2	75	15	0.	0.	******	68.00	0.08	0.00	24.56	17.92	33.0	9.14	19.0	7.0	12.00	7.40	1.85
9	2	75	16	0.	0.	******	30.50	0.02	0.00	22.68	17.40	34.0	9.13	19.0	7.2	12.00	6.65	1.60
9	2	75	17	0.	0.	50.50	35.00	0.03	0.00	23.48	17.92	34.0	9.11	19.0	7.5	12.00	5.90	1.35
9	2	75	18	0.	0.	******	50.00	0.06	0.00	25.44	18.36	33.0	9.06	19.0	6.8	29.33	14.60	4.35
9	2	75	19	0.	0.	******	45.50	0.09	0.00	43.27	33.91	31.0	9.02	19.0	7.1	29.33	13.40	3.70

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C°	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
9	2	75	20	0.	0.	66.00	49.50	0.04	0.00	22.59	17.62	31.0	9.00	19.0	7.8	29.33	11.60	3.30
9	2	75	21	0.	0.	******	29.00	0.16	0.00	22.40	11.40	24.0	8.91	18.0	6.2	3.00	1.45	0.00
9	2	75	22	0.	0.	******	28.00	0.16	0.00	21.95	11.57	22.0	8.91	18.0	6.2	3.00	1.05	0.00
9	2	75	23	0.	0.	35.50	25.00	0.09	0.00	22.26	11.79	21.0	8.90	19.0	6.7	3.00	0.85	0.00
9	4	75	10	40.	30.	56.81	******	0.02	0.00	29.39	26.93	25.0	9.40	19.0	12.8	0.00	0.00	0.00
9	4	75	11	4300.	40.	32.97	******	0.13	0.00	17.70	3.30	13.0	8.88	19.0	8.2	0.00	0.00	0.00
9	4	75	12	23.	0.	******	33.50	0.04	0.00	23.43	22.60	29.0	9.29	19.0	9.5	2.00	0.70	0.00
9	4	75	13	9.	0.	******	33.00	0.05	0.00	26.93	23.27	30.0	9.30	19.0	9.5	2.00	0.50	0.00
9	4	75	14	6.	0.	51.00	32.50	0.05	0.00	23.27	22.67	30.0	9.22	19.0	9.4	2.00	0.65	0.00
9	4	75	15	0.	0.	******	33.00	0.03	0.00	22.40	19.58	35.0	9.17	18.0	9.7	10.00	6.90	1.80
9	4	75	16	0.	0.	******	33.00	0.02	0.00	22.36	18.67	34.0	9.12	18.0	9.4	10.00	5.40	1.50
9	4	75	17	0.	0.	63.00	26.00	0.03	0.00	21.80	19.65	34.0	9.11	18.0	9.6	10.00	5.00	1.20
9	4	75	18	0.	0.	******	47.00	0.02	0.00	22.86	19.76	35.0	9.10	19.0	9.2	24.67	12.20	1.70
9	4	75	19	0.	0.	******	49.50	0.03	0.00	21.72	18.12	34.0	9.08	18.0	8.7	24.67	11.20	3.20
9	4	75	20	0.	0.	62.50	47.00	0.03	0.00	21.20	18.28	34.0	9.00	18.0	9.2	24.67	10.20	2.80
9	4	75	21	150.	3.	******	24.00	0.13	0.00	11.26	7.36	11.0	8.93	19.0	6.4	2.00	1.00	0.00
9	4	75	22	39.	7.	******	24.00	0.12	0.00	11.17	6.67	11.0	8.90	18.0	7.0	2.00	0.90	0.00
9	4	75	23	33.	7.	29.00	22.00	0.05	0.00	12.36	6.50	12.0	8.95	18.0	6.2	2.00	0.85	0.00
9	9	75	10	150.	40.	75.24	42.92	0.04	0.00	26.97	26.60	25.0	9.30	19.0	13.4	0.00	0.00	0.00
9	9	75	11	110.	30.	39.05	33.87	0.11	0.00	9.30	6.09	8.7	8.98	19.0	7.3	0.00	0.00	0.00
9	9	75	12	120.	9.	******	33.00	0.11	0.00	20.20	19.75	25.0	9.32	19.0	8.7	0.50	0.50	0.00
9	9	75	13	240.	43.	******	36.50	0.12	0.00	22.00	23.25	25.0	9.39	19.0	8.7	0.50	0.65	0.00
9	9	75	14	70.	7.	76.00	42.50	0.11	0.00	21.16	20.40	26.0	9.37	19.0	8.7	0.50	0.45	0.00
9	9	75	15	9.	0.	******	32.50	0.16	0.00	19.20	18.30	23.0	9.38	19.0	8.8	1.00	0.95	0.00
9	9	75	16	7.	0.	******	33.00	0.12	0.00	18.92	18.16	23.0	9.35	19.0	9.4	1.00	0.85	0.00
9	9	75	17	7.	0.	59.00	37.50	0.11	0.00	19.96	18.00	25.0	9.35	19.0	9.4	1.00	0.75	0.00
9	9	75	18	0.	0.	******	43.00	0.26	0.00	17.86	15.66	22.0	9.29	20.0	9.1	6.00	2.75	0.20
9	9	75	19	0.	0.	******	43.50	0.12	0.00	20.15	17.65	27.0	9.32	20.0	8.8	6.00	2.35	0.15
9	9	75	20	0.	0.	50.00	30.50	0.09	0.00	18.65	18.75	26.0	9.21	20.0	9.6	6.00	1.95	0.10
9	9	75	21	16.	0.	******	35.00	0.11	0.00	10.49	5.20	9.4	8.98	19.0	6.0	1.00	0.63	0.00
9	9	75	22	4.	0.	******	35.00	0.10	0.00	8.84	4.32	9.4	8.97	19.0	6.5	1.00	0.55	0.00
9	9	75	23	6.	0.	36.50	35.00	0.09	0.00	8.66	4.36	9.4	8.98	19.0	5.7	1.00	0.45	0.00
9	16	75	10	4300.	30.	73.61	63.97	0.43	0.00	19.67	38.42	28.0	9.20	****	****	0.00	0.00	0.00
9	16	75	11	9300.	30.	32.46	27.70	0.07	0.00	7.20	4.24	7.3	8.65	****	****	0.00	0.00	0.00
9	16	75	12	2400.	9.	******	35.00	0.37	0.00	36.60	31.20	31.0	9.21	****	****	0.50	0.15	0.00
9	16	75	13	930.	9.	******	48.50	0.35	3.00	32.25	30.67	30.0	9.25	****	****	0.50	0.20	0.00
9	16	75	14	750.	23.	58.00	41.00	0.53	0.00	36.08	32.33	30.0	9.23	****	****	0.50	0.25	0.00
9	16	75	15	0.	0.	******	41.00	0.35	0.00	32.93	27.13	39.0	9.21	****	****	4.00	3.30	0.00
9	16	75	16	0.	0.	******	33.00	0.35	0.00	31.85	29.85	38.0	9.20	****	****	4.00	2.95	0.00
9	16	75	17	0.	0.	54.50	30.00	0.37	0.00	30.42	30.75	40.0	9.22	****	****	4.00	2.70	0.00
9	16	75	18	4.	0.	******	33.00	0.20	0.00	32.61	23.33	42.0	9.17	****	****	10.00	3.60	0.50
9	16	75	19	0.	0.	******	63.00	0.16	0.00	29.82	29.09	43.0	9.13	****	****	10.00	3.30	0.30
9	16	75	20	0.	0.	63.00	35.50	0.18	0.00	31.95	29.69	44.0	9.12	****	****	10.00	3.10	0.10
9	16	75	21	430.	0.	******	******	0.05	0.00	9.36	5.39	8.2	8.62	****	****	0.50	0.50	0.00
9	16	75	22	230.	0.	******	49.00	0.04	0.00	9.12	5.46	8.3	8.60	****	****	0.50	0.65	0.00
9	16	75	23	150.	0.	3.00	36.00	0.07	0.00	8.16	5.10	5.6	8.40	****	****	0.50	0.45	0.00
9	18	75	10	3900.	30.	64.13	30.83	0.68	0.00	16.07	25.87	25.0	9.00	18.0	10.6	0.00	0.00	0.00
9	18	75	11	930.	30.	31.60	28.70	0.24	0.00	10.20	3.94	11.0	8.80	16.5	7.2	0.00	0.00	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
9	18	75	12	75.	4.	******	16.50	0.61	0.00	12.93	22.87	26.0	9.05	18.0	9.8	2.00	0.98	0.00
9	18	75	13	21.	0.	******	22.50	0.63	0.00	12.93	21.07	26.0	9.07	18.0	9.8	2.00	0.65	0.00
9	18	75	14	23.	0.	49.50	29.50	0.59	0.00	29.67	20.27	25.0	9.07	18.0	9.8	2.00	0.48	0.00
9	18	75	15	1500.	0.	******	26.00	0.64	0.00	30.75	21.25	26.0	9.08	18.0	9.7	0.25	0.13	0.00
9	18	75	16	1500.	0.	******	27.00	0.57	0.00	29.06	19.81	25.0	9.10	18.0	9.7	0.25	0.00	0.00
9	18	75	17	1500.	7.	49.00	21.00	0.61	0.00	28.38	20.50	25.0	9.10	18.0	9.9	0.25	0.00	0.00
9	18	75	18	0.	0.	******	33.50	0.46	0.00	29.60	19.40	32.0	8.98	18.0	9.8	6.00	3.75	0.00
9	18	75	19	0.	0.	******	17.00	0.42	0.00	30.05	20.85	32.0	8.95	18.0	9.7	6.00	3.38	0.00
9	18	75	20	0.	0.	49.50	28.50	0.46	0.00	29.23	21.33	34.0	8.98	18.0	9.8	6.00	3.15	0.00
9	18	75	21	0.	0.	******	25.00	0.18	0.00	11.00	4.36	12.0	8.81	16.5	6.8	4.00	1.85	0.00
9	18	75	22	4.	0.	******	20.00	0.18	0.00	10.72	4.92	11.0	8.80	16.5	6.6	4.00	1.63	0.00
9	18	75	23	4.	0.	17.00	14.00	0.21	0.00	11.54	4.48	11.0	8.80	16.5	6.8	4.00	1.48	0.00
9	23	75	10	230.	30.	77.43	36.83	0.82	0.00	29.80	20.83	17.0	9.25	16.0	14.0	0.00	0.00	0.00
9	23	75	11	430.	30.	45.65	32.63	0.67	0.00	11.46	4.54	11.0	9.78	16.0	8.6	0.00	0.00	0.00
9	23	75	12	53.	23.	******	35.50	0.79	0.00	29.00	19.04	21.0	9.15	16.0	10.4	1.00	0.65	0.00
9	23	75	13	43.	23.	******	35.50	0.83	0.00	6.17	16.33	17.0	9.22	16.0	10.2	1.00	0.40	0.00
9	23	75	14	9.	5.	57.00	37.50	0.60	0.00	25.16	16.72	19.0	9.25	16.0	10.4	1.00	0.40	0.00
9	23	75	15	230.	9.	******	31.50	0.80	0.00	27.36	16.89	19.0	9.27	16.0	10.8	0.50	0.45	0.00
9	23	75	16	93.	3.	******	35.00	0.66	0.00	28.92	17.80	20.0	9.29	16.0	10.6	0.50	0.30	0.00
9	23	75	17	30.	2.	39.00	36.00	0.90	0.00	25.95	16.70	20.0	9.29	16.0	10.7	0.50	0.35	0.00
9	23	75	18	5.	0.	******	29.00	0.64	0.00	24.85	16.25	20.0	9.25	16.0	10.3	4.00	3.60	0.00
9	23	75	19	2.	0.	******	15.50	0.76	0.00	25.33	15.90	20.0	9.00	16.0	10.2	4.00	3.50	0.00
9	23	75	20	5.	0.	51.00	34.00	0.07	0.00	24.90	15.85	21.0	9.00	16.0	10.3	4.00	3.40	0.00
9	23	75	21	0.	0.	******	27.00	0.40	0.00	17.04	5.74	12.0	8.70	16.0	7.2	6.00	1.85	0.35
9	23	75	22	0.	0.	******	31.00	0.15	0.00	16.66	5.66	12.0	8.38	16.0	7.8	6.00	1.40	0.20
9	23	75	23	0.	0.	42.00	30.50	0.14	0.00	18.19	6.96	12.0	8.60	16.0	7.8	6.00	1.15	0.15
9	25	75	10	930.	30.	45.70	38.55	1.05	0.00	16.43	11.76	10.0	9.25	16.0	14.4	0.00	0.00	0.00
9	25	75	11	1500.	30.	36.71	32.05	0.29	0.00	11.16	4.19	5.6	9.00	15.0	6.7	0.00	0.00	0.00
9	25	75	12	38.	8.	******	36.00	0.50	0.00	15.57	9.30	10.5	9.30	16.0	14.0	2.00	1.10	0.00
9	25	75	13	43.	2.	******	30.50	0.82	0.00	15.76	13.31	11.0	9.36	16.0	14.7	2.00	0.95	0.00
9	25	75	14	43.	5.	47.00	36.50	0.78	0.00	16.09	13.28	11.0	9.32	16.0	14.7	2.00	0.85	0.00
9	25	75	15	43.	15.	******	34.00	0.56	0.00	16.52	13.90	11.0	9.34	16.0	14.7	0.25	0.00	0.00
9	25	75	16	230.	15.	******	13.00	0.81	0.00	15.95	7.56	11.0	9.32	16.0	14.9	0.25	0.00	0.00
9	25	75	17	230.	5.	39.50	27.00	1.17	0.00	16.24	13.36	11.0	9.35	16.0	14.5	0.25	0.00	0.00
9	25	75	18	0.	0.	******	27.50	0.47	0.00	17.57	12.09	11.0	9.28	16.0	14.8	6.00	3.80	0.17
9	25	75	19	0.	0.	******	34.00	0.41	0.00	15.85	9.54	16.0	9.30	16.0	14.2	6.00	3.40	0.00
9	25	75	20	0.	0.	36.00	25.50	0.57	0.00	15.23	9.83	15.0	9.28	16.0	14.7	6.00	3.25	0.00
9	25	75	21	430.	0.	******	31.50	0.31	0.00	10.33	3.90	10.0	9.02	15.0	7.2	0.25	0.25	0.00
9	25	75	22	930.	0.	******	34.00	0.21	0.00	11.64	4.36	10.5	9.03	15.0	7.3	0.25	0.25	0.00
9	25	75	23	430.	2.	37.00	36.00	0.28	0.00	11.44	4.73	10.5	9.00	15.0	7.6	0.25	0.30	0.00
9	30	75	10	4300.	30.	29.56	35.41	1.32	0.00	14.32	4.13	****	9.09	15.0	6.2	0.00	0.00	0.00
9	30	75	11	4300.	40.	24.26	22.93	0.47	0.00	4.94	2.30	****	8.79	15.0	5.4	0.00	0.00	0.00
9	30	75	12	2400.	12.	30.42	47.89	1.47	0.00	14.14	6.57	****	9.43	15.0	6.3	1.00	0.55	0.00
9	30	75	13	930.	0.	******	30.34	1.43	0.00	17.84	6.52	****	9.10	15.0	5.4	1.00	0.30	0.00
9	30	75	14	240.	2.	29.88	27.22	1.34	0.00	10.99	4.36	****	9.02	15.0	6.1	1.00	0.30	0.00
9	30	75	15	930.	0.	******	20.75	1.38	0.00	14.14	6.16	****	9.05	15.0	6.2	0.50	0.40	0.00
9	30	75	16	230.	0.	******	29.56	1.31	0.00	14.52	6.76	****	8.89	15.0	6.2	0.50	0.35	0.00
9	30	75	17	53.	5.	32.53	36.58	2.21	0.00	13.84	6.14	****	9.05	15.0	6.2	0.50	0.35	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/I	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C°	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
9	30	75	18	0.	0.	******	29.88	1.50	0.00	14.38	6.70	****	8.95	16.0	6.3	8.00	6.60	0.00
9	30	75	19	0.	0.	24.34	29.49	1.83	0.00	13.82	6.62	****	8.80	16.0	6.2	8.00	6.10	0.00
9	30	75	20	0.	0.	33.93	30.27	1.34	0.00	13.72	5.92	****	8.90	16.0	6.1	8.00	6.00	0.00
9	30	75	21	2400.	5.	******	10.84	0.47	0.00	8.84	2.76	****	8.81	15.0	5.9	0.50	0.50	0.00
9	30	75	22	430.	5.	******	27.69	0.58	0.00	8.34	2.20	****	8.83	15.0	6.3	0.50	0.40	0.00
9	30	75	23	140.	2.	22.62	22.54	0.61	0.00	8.50	2.06	****	8.82	15.0	6.9	0.50	0.35	0.00
10	7	75	10	9300.	2300.	53.85	33.45	7.21	0.00	32.38	12.74	****	8.65	16.0	2.5	0.00	0.00	0.00
10	7	75	11	15000.	93.	32.40	18.98	4.71	0.00	8.50	2.86	****	8.50	16.0	7.3	0.00	0.00	0.00
10	7	75	12	11000.	430.	49.20	******	7.12	0.00	43.65	14.10	****	8.55	16.0	4.7	1.00	0.63	0.00
10	7	75	13	11000.	93.	******	26.70	7.46	0.00	52.47	16.00	****	8.60	16.0	4.7	1.00	0.49	0.00
10	7	75	14	1500.	230.	50.85	36.44	7.01	0.00	37.70	13.50	****	8.65	16.0	4.6	1.00	0.39	0.00
10	7	75	15	2400.	230.	******	38.90	7.39	0.00	42.15	12.00	****	8.64	16.0	4.7	0.50	0.50	0.00
10	7	75	16	1500.	940.	******	25.05	7.24	0.00	39.35	12.40	****	8.60	16.0	4.5	0.50	0.50	0.00
10	7	75	17	930.	23.	49.75	19.20	7.10	0.00	39.25	11.10	****	8.66	16.0	4.6	0.50	0.50	0.00
10	7	75	18	21.	0.	******	32.55	6.84	0.00	45.15	14.30	****	8.48	16.0	4.8	4.00	3.01	0.00
10	7	75	19	2.	0.	******	19.29	6.95	0.00	41.15	13.80	****	8.48	16.0	4.9	4.00	2.91	0.00
10	7	75	20	2.	0.	51.05	21.60	7.46	0.00	38.10	12.70	****	8.58	16.0	4.8	4.00	2.82	0.00
10	7	75	21	430.	2.	******	31.25	4.56	0.00	10.40	4.90	****	8.43	16.0	7.1	2.00	1.17	0.00
10	7	75	22	2.	0.	******	56.25	4.49	0.00	6.26	2.60	****	8.45	16.0	6.8	2.00	1.04	0.00
10	7	75	23	0.	0.	35.45	33.40	4.54	0.00	8.02	2.44	****	8.50	16.0	7.4	2.00	0.97	0.00
10	9	75	10	930.	90.	47.01	20.63	3.89	0.00	24.10	9.85	****	8.50	13.0	3.4	0.00	0.00	0.00
10	9	75	11	930.	30.	43.07	17.95	3.54	0.00	4.56	3.20	11.0	8.30	12.0	9.4	0.00	0.00	0.00
10	9	75	12	210.	9.	41.50	26.14	3.66	0.00	21.96	8.66	15.0	8.30	13.0	7.0	2.00	0.95	0.00
10	9	75	13	43.	0.	******	22.21	4.49	0.00	14.33	6.40	11.0	8.40	13.0	7.4	2.00	0.88	0.00
10	9	75	14	43.	0.	36.93	18.50	4.14	0.00	11.72	8.84	10.0	8.50	13.0	7.5	2.00	0.88	0.00
10	9	75	15	430.	21.	******	29.21	3.98	0.00	20.70	7.67	15.0	8.50	13.0	7.1	0.25	0.25	0.00
10	9	75	16	230.	93.	******	31.02	4.05	0.00	23.23	8.13	15.0	8.50	13.0	7.5	0.25	0.22	0.00
10	9	75	17	93.	240.	38.03	26.14	3.75	0.00	18.40	7.40	12.0	8.50	13.0	7.5	0.25	0.17	0.00
10	9	75	18	0.	0.	******	45.28	3.54	0.00	19.87	7.57	15.0	8.30	13.0	7.0	6.00	4.61	0.00
10	9	75	19	0.	0.	******	19.21	3.77	0.00	18.70	7.50	15.0	8.20	13.0	7.6	6.00	4.56	0.00
10	9	75	20	0.	0.	30.08	23.47	3.61	0.00	18.17	7.17	15.0	8.30	13.0	7.4	6.00	4.42	0.00
10	9	75	21	75.	0.	******	32.44	2.55	0.00	7.24	2.38	7.4	8.40	12.0	7.7	1.00	0.98	0.00
10	9	75	22	9.	0.	******	14.88	2.48	0.00	7.40	2.54	8.0	8.40	12.0	7.5	1.00	0.90	0.00
10	9	75	23	5.	0.	53.46	25.98	3.10	0.00	6.98	2.54	7.5	8.40	12.0	7.5	1.00	0.85	0.00
10	14	75	10	230.	20.	33.60	33.28	4.85	0.00	18.24	6.28	****	7.83	11.0	2.7	0.00	0.00	0.00
10	14	75	11	2300.	20.	23.00	12.49	2.66	0.00	5.34	2.16	****	7.95	10.0	6.6	0.00	0.00	0.00
10	14	75	12	0.	0.	******	29.33	4.64	0.00	15.38	4.00	****	8.12	11.0	5.0	4.00	2.55	0.00
10	14	75	13	0.	0.	******	25.53	4.90	0.00	15.08	4.24	****	8.22	11.0	4.9	4.00	2.45	0.00
10	14	75	14	0.	0.	35.81	29.72	4.72	0.00	15.22	4.74	****	8.19	11.0	5.3	4.00	2.33	0.00
10	14	75	15	220.	0.	******	30.04	7.42	0.00	15.96	5.27	****	8.20	11.0	4.8	0.50	0.47	0.00
10	14	75	16	46.	0.	******	31.84	4.90	0.00	15.03	5.38	****	8.11	11.0	5.1	0.50	0.42	0.00
10	14	75	17	27.	0.	35.02	33.44	3.33	0.00	15.20	5.45	****	8.10	11.0	5.1	0.50	0.37	0.00
10	14	75	18	0.	0.	******	38.34	3.27	0.00	15.00	5.00	****	7.88	11.0	5.1	24.14	14.00	0.00
10	14	75	19	0.	0.	******	26.48	4.85	0.00	13.58	4.58	****	7.72	11.0	4.7	24.14	13.48	0.00
10	14	75	20	0.	0.	******	33.44	4.38	0.00	15.23	5.40	****	7.83	11.0	4.9	24.14	13.32	0.00
10	14	75	21	0.	0.	******	17.23	1.70	0.00	5.54	2.36	****	7.89	10.0	7.0	4.00	2.55	0.00
10	14	75	22	0.	0.	******	20.95	2.68	0.00	5.90	2.26	****	7.91	10.0	7.1	4.00	2.48	0.00
10	14	75	23	0.	0.	34.68	18.02	3.45	0.00	5.42	2.16	****	8.01	10.0	7.5	4.00	2.43	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
10	21	75	10	90.	20.	20.60	16.74	6.34	0.00	12.92	5.64	12.0	8.10	11.0	3.0	0.00	0.00	0.00
10	21	75	11	3300.	20.	24.25	17.78	7.67	0.00	11.20	3.44	14.0	8.00	11.0	6.4	0.00	0.00	0.00
10	21	75	12	0.	0.	******	17.93	4.49	0.00	11.75	3.96	17.0	8.10	12.0	4.6	6.00	3.54	0.00
10	21	75	13	0.	0.	******	32.88	4.49	0.00	11.32	3.76	12.0	8.10	12.0	4.7	6.00	3.51	0.00
10	21	75	14	0.	0.	20.68	15.92	6.34	0.00	10.48	3.28	13.0	8.10	12.0	5.0	6.00	3.51	0.00
10	21	75	15	4.	0.	******	22.24	6.78	0.00	10.94	3.24	18.0	8.05	12.0	4.7	1.00	0.97	0.00
10	21	75	16	2.	0.	******	37.76	8.36	0.00	11.16	1.24	17.0	8.15	12.0	4.9	1.00	0.90	0.00
10	21	75	17	2.	0.	22.24	18.37	6.85	0.00	10.80	3.78	12.0	8.15	12.0	4.9	1.00	0.80	0.00
10	21	75	18	0.	0.	******	4.61	5.65	0.00	10.44	3.28	14.0	7.80	12.0	5.0	26.00	12.40	0.00
10	21	75	19	0.	0.	******	15.32	6.78	0.00	11.28	3.65	15.0	7.80	12.0	4.8	26.00	12.00	0.00
10	21	75	20	0.	0.	20.75	19.12	5.58	0.00	10.80	3.65	13.0	7.90	12.0	5.0	26.00	11.80	0.00
10	21	75	21	0.	0.	******	31.46	3.60	0.00	12.00	3.04	17.0	7.95	12.0	6.6	6.00	3.54	0.00
10	21	75	22	0.	0.	******	21.12	5.24	0.00	11.08	2.68	17.0	8.00	12.0	6.9	6.00	3.49	0.00
10	21	75	23	0.	0.	18.82	******	6.47	0.00	10.48	2.54	17.0	8.05	12.0	7.4	6.00	3.41	0.00
10	23	75	10	1700.	140.	44.65	31.54	5.14	0.00	12.24	5.28	****	****	10.0	5.0	0.00	0.00	0.00
10	23	75	11	7000.	490.	30.10	29.56	3.01	0.00	13.84	6.16	****	****	8.0	9.8	0.00	0.00	0.00
10	23	75	12	110.	7.	******	49.60	4.96	0.00	10.24	3.88	****	8.03	10.0	7.1	2.00	1.05	0.00
10	23	75	13	6.	4.	******	31.70	5.75	0.00	11.50	4.44	****	8.05	10.0	8.9	2.00	1.02	0.00
10	23	75	14	6.	4.	35.28	29.56	5.10	0.00	15.00	6.68	****	8.15	10.0	7.8	2.00	1.00	0.00
10	23	75	15	2400.	94.	******	27.20	4.96	0.00	10.16	3.70	****	8.11	10.0	8.0	0.25	0.00	0.00
10	23	75	16	230.	22.	******	27.05	4.92	0.00	10.94	3.58	****	8.09	10.0	8.0	0.25	0.00	0.00
10	23	75	17	230.	27.	31.62	28.65	4.84	0.00	11.48	3.62	****	8.17	10.0	8.7	0.25	0.00	0.00
10	23	75	18	2.	2.	******	8.61	4.40	0.00	13.14	4.48	****	7.80	10.0	9.1	25.58	12.40	0.00
10	23	75	19	0.	0.	******	28.57	4.43	0.00	13.38	4.76	****	7.79	10.0	8.9	25.58	12.00	0.00
10	23	75	20	0.	0.	38.48	35.43	7.17	0.00	11.65	3.90	****	7.83	10.0	7.8	25.58	11.60	0.00
10	23	75	21	24000.	330.	******	30.25	3.17	0.00	13.90	4.16	****	8.09	8.0	11.2	0.25	0.25	0.00
10	23	75	22	2400.	49.	******	32.31	3.27	0.00	13.02	2.52	****	8.09	8.0	12.2	0.25	0.00	0.00
10	23	75	23	1800.	28.	35.28	31.47	3.03	0.00	9.74	0.58	****	8.16	8.0	12.0	0.25	0.00	0.00
10	30	75	10	490.	330.	34.53	23.75	4.78	0.00	8.90	3.83	****	8.46	7.0	5.2	0.00	0.00	0.00
10	30	75	11	2200.	230.	24.50	33.30	3.54	0.00	8.16	2.53	****	8.51	6.5	9.5	0.00	0.00	0.00
10	30	75	12	0.	0.	******	29.68	4.80	0.00	9.02	3.28	****	8.08	7.0	7.0	4.00	2.25	0.00
10	30	75	13	0.	0.	******	27.95	4.11	0.00	8.56	3.24	****	8.09	7.0	8.0	4.00	2.20	0.00
10	30	75	14	0.	0.	28.96	16.65	4.73	0.00	8.32	2.42	****	8.17	7.0	8.0	4.00	2.15	0.00
10	30	75	15	330.	46.	******	27.29	4.48	0.00	9.02	3.18	****	8.16	7.0	8.0	0.50	0.40	0.00
10	30	75	16	17.	5.	******	26.06	4.98	0.00	8.74	3.22	****	8.19	7.0	7.5	0.50	0.30	0.00
10	30	75	17	17.	2.	30.48	25.20	4.68	0.00	8.74	3.22	****	8.35	7.0	7.7	0.50	0.30	0.00
10	30	75	18	0.	0.	******	28.45	4.98	0.00	8.88	3.16	****	7.82	7.0	8.1	18.97	6.40	0.00
10	30	75	19	0.	0.	******	29.68	4.46	0.00	8.84	3.26	****	8.80	7.0	7.2	18.97	6.20	0.00
10	30	75	20	0.	0.	35.84	34.61	4.40	0.00	9.02	3.00	****	7.82	7.0	8.0	18.97	6.20	0.00
10	30	75	21	790.	33.	******	23.61	3.64	0.00	8.38	1.95	****	8.03	6.5	9.7	0.50	0.50	0.00
10	30	75	22	230.	8.	******	24.62	2.92	0.00	8.46	2.30	****	8.10	6.5	9.8	0.50	0.45	0.00
10	30	75	23	130.	2.	33.16	25.48	3.51	0.00	8.98	2.22	****	8.24	6.5	10.2	0.50	0.40	0.00
11	4	75	10	220.	40.	27.78	23.22	5.16	0.00	8.70	3.60	8.0	8.10	8.0	6.8	0.00	0.00	0.00
11	4	75	11	3300.	20.	21.00	19.53	4.10	0.00	8.27	2.67	9.4	8.05	8.0	10.0	0.00	0.00	0.00
11	4	75	12	0.	0.	33.68	21.74	4.88	0.00	8.36	3.20	8.7	8.08	8.0	7.0	6.00	3.83	0.00
11	4	75	13	0.	0.	******	23.95	4.63	0.00	7.70	2.92	8.0	8.17	9.0	7.2	6.00	3.79	0.00
11	4	75	14	0.	0.	25.06	24.62	4.84	0.00	8.00	2.72	8.4	8.08	8.0	6.9	6.00	3.54	0.00
11	4	75	15	0.	0.	******	27.42	4.82	0.00	7.80	2.98	8.4	8.14	9.0	6.4	1.00	1.04	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
11	4	75	16	2.	0.	******	26.90	5.16	0.00	8.40	2.92	8.6	8.12	8.0	6.4	1.00	0.95	0.00
11	4	75	17	2.	0.	24.54	26.16	5.10	0.00	8.04	2.92	8.5	8.10	8.0	6.9	1.00	0.90	0.00
11	4	75	18	0.	0.	******	21.00	4.82	0.00	9.10	3.10	8.3	7.90	8.0	6.7	14.75	8.54	0.00
11	4	75	19	0.	0.	******	24.69	4.86	0.00	8.10	2.60	8.2	7.90	8.0	6.9	14.75	8.34	0.00
11	4	75	20	0.	0.	25.43	26.16	4.86	0.00	8.10	2.92	8.4	7.90	8.0	6.6	14.75	8.34	0.00
11	4	75	21	33.	0.	******	23.58	3.60	0.00	8.66	2.26	9.5	8.12	8.0	9.6	1.00	1.00	0.00
11	4	75	22	0.	0.	******	18.79	3.74	0.00	8.06	2.14	9.2	8.07	8.0	9.3	1.00	1.00	0.00
11	4	75	23	0.	0.	26.16	19.83	3.92	0.00	8.50	2.02	9.0	8.10	8.0	9.2	1.00	1.00	0.00
11	6	75	10	20.	20.	18.76	23.36	5.66	0.00	8.22	2.84	****	8.58	8.5	****	0.00	0.00	0.00
11	6	75	11	490.	20.	19.19	22.35	5.70	0.00	7.64	2.34	****	8.52	7.5	****	0.00	0.00	0.00
11	6	75	12	8.	0.	23.07	20.05	7.07	0.00	8.58	3.34	****	8.13	8.5	****	2.00	1.25	0.00
11	6	75	13	5.	0.	******	20.27	6.25	0.00	6.46	2.58	****	8.15	8.5	****	2.00	1.10	0.00
11	6	75	14	5.	0.	25.94	22.71	10.06	0.00	5.88	2.64	****	8.20	8.5	****	2.00	1.05	0.00
11	6	75	15	8.	0.	******	19.48	5.74	0.00	8.76	3.14	****	8.15	8.5	****	0.25	0.30	0.00
11	6	75	16	5.	0.	******	22.28	5.43	0.00	7.06	2.50	****	8.30	8.5	****	0.25	0.25	0.00
11	6	75	17	2.	0.	22.28	18.76	6.21	0.00	8.12	3.10	****	8.19	8.5	****	0.25	0.20	0.00
11	6	75	18	0.	0.	******	20.76	5.35	0.00	10.12	3.50	****	7.90	8.5	****	10.00	4.40	0.00
11	6	75	19	0.	0.	******	17.54	5.55	0.00	9.93	3.50	****	7.98	8.5	****	10.00	4.30	0.00
11	6	75	20	0.	0.	24.15	20.70	5.20	0.00	9.64	4.10	****	7.90	8.5	****	10.00	4.20	0.00
11	6	75	21	0.	0.	******	20.19	5.70	0.00	7.50	2.42	****	8.03	7.5	****	2.00	2.25	0.00
11	6	75	22	0.	0.	******	19.04	6.45	0.00	10.50	2.82	****	8.19	7.5	****	2.00	2.10	0.00
11	6	75	23	0.	0.	21.56	22.21	5.12	0.00	6.38	2.20	****	8.13	7.5	****	2.00	2.00	0.00
11	11	75	10	54000.	4600.	28.02	29.11	7.16	0.00	12.34	4.82	****	****	6.0	7.2	0.00	0.00	0.00
11	11	75	11	1700.	20.	23.35	24.13	4.92	0.00	6.24	2.22	****	****	6.0	7.7	0.00	0.00	0.00
11	11	75	12	24000.	9200.	******	26.38	7.33	0.00	12.12	4.50	8.7	9.28	6.0	7.8	0.00	0.00	0.00
11	11	75	13	24000.	9200.	******	25.53	6.10	0.00	12.26	4.72	5.3	8.28	6.0	7.8	0.00	0.00	0.00
11	11	75	14	3500.	3500.	26.30	25.60	6.48	0.00	11.70	3.56	9.8	8.30	6.0	7.8	0.00	0.00	0.00
11	11	75	15	9200.	2200.	******	26.62	6.57	0.00	10.92	4.36	9.5	8.21	6.0	7.8	0.50	0.45	0.00
11	11	75	16	1700.	490.	******	23.19	8.48	0.00	11.96	4.66	10.0	8.22	6.0	7.8	0.50	0.37	0.00
11	11	75	17	1300.	490.	29.57	28.02	6.14	0.00	11.30	4.60	14.0	8.28	6.0	7.8	0.50	0.30	0.00
11	11	75	18	170.	70.	******	27.24	6.06	0.00	11.60	4.52	10.0	8.15	6.0	7.5	4.00	3.27	0.00
11	11	75	19	0.	0.	******	25.06	6.70	0.00	11.72	10.68	12.0	8.13	6.0	7.9	4.00	3.07	0.00
11	11	75	20	0.	0.	29.73	26.46	6.14	0.00	11.70	4.48	11.0	8.19	6.0	7.9	4.00	3.02	0.00
11	11	75	21	20.	20.	******	24.90	5.34	0.00	6.86	2.18	8.9	8.02	6.0	8.0	4.00	3.19	0.00
11	11	75	22	20.	20.	******	22.65	4.92	0.00	6.88	2.12	7.4	8.10	6.0	8.3	4.00	3.17	0.00
11	11	75	23	20.	20.	31.13	21.56	5.93	0.00	6.70	2.22	7.2	8.10	6.0	8.6	4.00	3.32	0.00
11	13	75	10	3300.	790.	43.28	20.78	5.55	0.00	3.27	5.20	6.7	8.16	5.0	6.2	0.00	0.00	0.00
11	13	75	11	4900.	1100.	17.34	22.50	4.92	0.00	10.53	4.60	8.6	8.12	4.5	9.5	0.00	0.00	0.00
11	13	75	15	31.	13.	******	18.44	11.18	0.00	6.04	2.68	9.4	8.16	5.0	8.7	1.00	0.92	0.00
11	13	75	16	2.	0.	******	19.53	6.72	0.00	8.16	3.24	8.6	8.21	5.0	8.3	1.00	0.75	0.00
11	13	75	17	2.	0.	25.70	22.73	7.32	0.00	7.64	4.04	8.5	8.23	5.0	8.5	1.00	0.65	0.00
11	13	75	18	0.	0.	******	18.44	12.01	0.00	11.16	3.44	10.0	8.16	5.0	8.2	10.00	6.08	0.00
11	13	75	19	0.	0.	******	21.09	7.87	0.00	7.72	2.88	8.6	8.00	5.0	8.1	10.00	6.00	0.00
11	13	75	20	0.	0.	29.22	19.77	6.58	0.00	7.16	2.00	9.0	7.99	5.0	8.0	10.00	6.08	0.00
11	18	75	10	3300.	83.	31.42	29.11	5.05	0.00	12.80	3.14	****	8.34	5.0	8.0	0.00	0.00	0.00
11	18	75	11	54000.	80.	19.94	23.33	2.91	0.00	11.64	1.96	****	8.12	5.0	9.0	0.00	0.00	0.00
11	18	75	12	33.	8.	29.57	31.42	8.19	0.00	12.78	3.20	7.4	8.25	4.0	8.9	2.00	0.83	0.00
11	18	75	13	13.	2.	******	29.11	16.26	0.00	13.80	2.96	7.7	8.33	4.0	8.7	2.00	0.80	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /1004L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
11	18	75	14	11.	0.	30.49	27.57	5.79	0.00	16.20	3.20	8.1	8.32	4.0	8.3	2.00	0.80	0.00
11	18	75	15	49.	13.	******	29.80	14.22	0.00	6.32	2.82	7.0	8.38	5.0	8.2	0.25	0.25	0.00
11	18	75	16	79.	17.	******	28.95	6.31	0.00	6.30	2.66	6.1	8.30	5.0	8.3	0.25	0.24	0.00
11	18	75	17	27.	4.	29.11	29.57	7.04	0.00	6.36	5.16	8.5	8.50	5.0	8.0	0.25	0.22	0.00
11	18	75	18	0.	0.	******	20.56	4.61	0.00	6.30	2.36	7.6	8.08	5.0	8.4	15.00	8.58	0.00
11	18	75	19	0.	0.	******	24.64	6.86	0.00	19.54	2.32	5.8	7.98	5.0	8.3	15.00	8.48	0.00
11	18	75	20	0.	0.	34.57	24.03	7.93	0.00	6.30	2.54	8.0	8.02	5.0	8.3	15.00	8.44	0.00
11	18	75	21	0.	0.	******	23.72	4.76	0.00	6.00	1.28	6.0	8.12	5.0	9.1	6.00	3.95	0.00
11	18	75	22	0.	0.	******	27.57	3.30	0.00	6.10	2.10	5.9	8.11	5.0	10.0	6.00	3.93	0.00
11	18	75	23	0.	0.	19.17	23.18	6.86	0.00	3.52	1.96	5.8	8.13	5.0	10.0	6.00	3.90	0.00
11	25	75	10	20.	20.	24.32	28.92	5.69	0.00	5.55	3.05	****	8.17	4.0	7.8	0.00	0.00	0.00
11	25	75	11	270.	20.	21.90	22.68	3.70	0.00	3.33	3.60	6.6	8.11	4.0	9.0	0.00	0.00	0.00
11	25	75	12	5.	0.	******	23.38	4.83	0.00	3.86	3.28	7.1	8.25	4.0	10.8	4.00	2.17	0.00
11	25	75	13	13.	0.	******	21.90	4.21	0.00	4.16	3.32	6.1	8.00	4.5	10.8	4.00	2.02	0.00
11	25	75	14	2.	0.	27.20	27.12	5.24	0.00	4.60	3.02	7.2	8.22	4.5	10.3	4.00	1.98	0.00
11	25	75	15	34.	0.	******	25.02	4.45	0.00	3.52	3.04	6.2	8.20	4.5	9.2	0.50	0.41	0.00
11	25	75	16	79.	0.	******	22.06	5.03	0.00	4.42	3.60	6.5	8.26	4.5	9.5	0.50	0.29	0.00
11	25	75	17	49.	0.	45.36	27.83	5.24	0.00	5.50	4.26	7.0	8.33	4.5	10.4	0.50	0.22	0.00
11	25	75	18	0.	0.	22.68	27.59	4.73	0.00	3.34	2.86	5.9	8.30	4.5	9.5	19.48	10.84	0.00
11	25	75	19	0.	0.	******	26.58	4.01	0.00	3.48	2.32	6.4	7.98	4.5	10.4	19.48	10.44	0.00
11	25	75	20	0.	0.	26.11	25.62	5.86	0.00	3.86	2.96	6.2	8.07	4.5	9.6	19.48	10.44	0.00
11	25	75	21	3500.	0.	******	21.90	5.75	0.00	4.16	2.88	6.8	8.27	3.0	11.6	0.25	0.25	0.00
11	25	75	22	130.	13.	******	26.89	5.10	0.00	3.68	2.18	6.3	8.15	3.0	11.9	0.25	0.20	0.00
11	25	75	23	33.	0.	23.46	41.23	4.62	0.00	3.04	2.52	5.4	8.24	3.0	12.8	0.25	0.20	0.00
3	2	76	10	230000.	79000.	58.30	40.60	7.69	1.00	7.72	7.12	15.0	8.32	2.0	1.1	0.00	0.00	0.00
3	2	76	11	79000.	22000.	36.50	23.70	5.46	0.00	8.48	7.03	11.0	7.99	2.0	3.5	0.00	0.00	0.00
3	2	76	12	130000.	49000.	******	36.60	6.43	0.00	7.28	6.76	5.6	8.17	2.0	2.0	1.00	0.00	0.00
3	2	76	13	140000.	110000.	******	39.80	7.65	0.00	7.68	7.16	6.2	8.32	2.0	2.3	1.00	0.00	0.00
3	2	76	14	110000.	70000.	57.90	40.60	7.14	0.00	6.92	6.76	6.8	8.26	2.0	2.2	1.00	0.00	0.00
3	2	76	15	170000.	79000.	******	39.70	7.40	0.00	7.60	7.44	5.8	8.48	2.0	2.1	0.25	0.00	0.00
3	2	76	16	350000.	110000.	******	38.90	7.35	0.00	7.00	6.40	6.0	8.35	2.0	2.2	0.25	0.00	0.00
3	2	76	17	240000.	79000.	52.10	40.80	7.98	0.00	7.40	6.68	6.3	8.49	2.0	2.0	0.25	0.00	0.00
3	2	76	18	280000.	70000.	******	44.50	7.23	0.00	7.72	7.00	9.5	8.41	2.0	2.5	4.00	0.00	0.00
3	2	76	19	130000.	49000.	******	36.80	6.89	0.00	8.32	6.72	9.5	8.19	2.0	2.7	4.00	0.00	0.00
3	2	76	20	130000.	33000.	56.50	38.30	7.02	0.00	8.52	9.40	9.6	8.38	2.0	2.8	4.00	0.00	0.00
3	2	76	21	3300.	1700.	******	25.30	3.87	0.00	11.52	6.44	8.8	8.25	2.0	3.7	2.00	1.05	0.00
3	2	75	22	220.	33.	******	25.30	3.24	0.00	10.20	6.12	9.4	8.27	2.0	4.2	2.00	1.00	0.00
3	2	76	23	110.	27.	37.10	23.00	3.91	0.00	10.72	5.88	9.8	8.38	2.0	4.7	2.00	0.90	0.00
3	4	76	10	490000.	220000.	46.64	26.64	7.71	1.20	8.60	7.88	16.0	8.18	2.5	0.4	0.00	0.00	0.00
3	4	76	11	33000.	33000.	25.31	14.90	5.23	0.30	9.04	5.90	7.7	8.00	1.0	2.9	0.00	0.00	0.00
3	4	76	12	140000.	94000.	******	31.48	9.52	0.56	7.80	7.32	6.4	8.13	2.5	2.0	6.00	0.40	0.00
3	4	76	13	130000.	49000.	******	21.59	8.82	0.56	7.76	7.76	8.3	8.38	2.5	2.2	6.00	0.25	0.00
3	4	76	14	33000.	33000.	47.53	26.05	7.71	0.50	8.08	7.36	10.0	8.23	2.5	2.4	6.00	0.20	0.00
3	4	76	15	130000.	49000.	******	24.19	7.97	0.60	8.03	7.56	9.0	8.22	2.5	1.8	2.00	0.00	0.00
3	4	76	16	130000.	79000.	******	26.05	7.12	0.58	8.12	7.92	10.2	8.38	2.5	2.0	2.00	0.00	0.00
3	4	76	17	540000.	70000.	52.43	26.79	7.67	0.54	7.68	7.28	10.1	8.22	2.5	2.3	2.00	0.00	0.00
3	4	76	18	500.	200.	******	27.16	7.52	0.48	7.08	6.76	6.8	7.88	2.5	2.2	9.83	2.40	0.00
3	4	76	19	50.	50.	******	37.42	7.56	0.42	7.84	7.24	6.6	8.12	2.5	2.6	9.83	2.30	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
3	4	76	20	50.	50.	46.64	29.02	7.08	0.39	7.68	7.50	6.6	7.99	2.5	2.5	9.83	2.25	0.00
3	4	76	21	170.	170.	******	14.31	4.86	0.30	7.88	5.64	7.2	8.29	1.0	3.4	4.00	2.20	0.00
3	4	76	22	8.	0.	******	17.13	5.15	0.30	8.00	5.28	7.3	8.11	1.0	3.6	4.00	2.05	0.00
3	4	76	23	7.	0.	10.44	24.93	4.86	0.30	8.00	4.96	7.6	8.23	1.0	4.0	4.00	2.00	0.00
3	9	76	10	490000.	330000.	64.94	38.00	10.35	1.00	19.44	17.40	11.0	7.72	2.0	0.5	0.00	0.00	0.00
3	9	76	11	130000.	49000.	37.00	24.40	7.04	0.14	6.60	6.20	5.0	7.72	1.0	1.5	0.00	0.00	0.00
3	9	76	12	240000.	240000.	******	43.24	9.72	0.52	7.36	7.08	8.6	7.88	2.0	3.0	6.00	0.00	0.00
3	9	76	13	240000.	240000.	******	39.76	10.41	0.52	8.48	8.04	7.7	7.80	2.0	2.7	6.00	0.00	0.00
3	9	76	14	350000.	110000.	59.90	38.64	10.12	0.54	8.80	8.48	12.0	7.89	2.0	2.9	6.00	0.00	0.00
3	9	76	15	350000.	350000.	******	37.50	10.35	0.78	9.76	9.44	14.0	7.87	2.0	2.6	0.50	0.00	0.00
3	9	76	16	920000.	350000.	******	36.35	9.83	0.74	8.72	8.24	8.6	7.90	2.0	2.7	0.50	0.00	0.00
3	9	76	17	240000.	49000.	62.90	37.50	9.89	0.74	8.80	8.52	8.5	8.10	2.0	2.7	0.50	0.00	0.00
3	9	76	18	9.	4.	******	36.35	9.77	0.45	8.08	7.60	7.3	7.73	2.0	2.8	14.75	3.45	0.00
3	9	76	19	0.	0.	******	38.00	9.66	0.48	8.32	7.44	7.4	7.64	2.0	2.6	14.75	3.30	0.00
3	9	76	20	0.	0.	60.45	34.79	9.38	0.45	8.36	8.28	7.9	7.80	2.0	3.0	14.75	3.25	0.00
3	9	76	21	230.	79.	******	22.94	7.78	0.16	5.72	5.72	5.0	7.75	1.0	3.0	6.00	3.45	0.00
3	9	76	22	2.	2.	******	24.23	6.98	0.13	6.28	5.96	5.6	7.82	1.0	3.5	6.00	3.30	0.00
3	9	76	23	0.	1.	22.94	38.73	7.44	0.12	6.24	5.24	6.1	7.83	1.0	3.8	6.00	3.30	0.00
3	11	76	10	330000.	330000.	62.71	38.26	8.08	1.25	21.40	21.10	28.0	8.28	3.0	0.6	0.00	0.00	0.00
3	11	76	11	79000.	49000.	33.40	12.43	6.00	0.00	5.64	5.20	5.2	8.20	1.5	1.0	0.00	0.00	0.00
3	11	76	12	230000.	130000.	******	45.98	7.27	0.61	8.52	8.52	10.0	8.12	2.5	2.7	6.00	0.02	0.00
3	11	76	13	790000.	70000.	******	36.39	7.73	0.63	8.80	8.68	17.0	7.97	2.5	2.8	6.00	0.00	0.00
3	11	76	14	280000.	180000.	62.90	52.86	7.42	0.65	9.28	8.52	18.0	8.02	2.5	2.9	6.00	0.00	0.00
3	11	76	15	500.	500.	******	39.39	7.19	0.63	9.32	8.36	22.0	7.89	2.5	3.8	8.00	2.02	0.00
3	11	76	16	500.	500.	******	36.54	7.58	0.63	9.36	7.84	21.0	7.90	2.5	2.8	8.00	1.98	0.00
3	11	76	17	500.	500.	57.58	36.77	6.50	0.63	8.04	7.44	15.0	7.91	2.5	3.1	8.00	1.90	0.00
3	11	76	18	0.	0.	******	38.19	6.69	0.65	8.92	8.60	12.0	7.82	2.5	3.4	19.48	5.90	0.00
3	11	76	19	0.	0.	******	37.14	6.96	0.64	8.64	8.24	19.0	7.80	2.5	3.1	19.48	5.62	0.00
3	11	76	20	0.	0.	58.11	37.14	7.50	0.65	8.24	7.88	21.0	7.85	2.5	3.3	19.48	5.33	0.00
3	11	76	21	5400.	3500.	******	22.84	6.19	0.00	6.44	5.68	7.5	7.98	1.5	3.3	1.00	0.48	0.00
3	11	76	22	16000.	3500.	******	25.98	5.92	0.00	6.12	5.08	8.0	8.00	1.5	2.8	1.00	0.38	0.00
3	11	76	23	1400.	1400.	34.89	23.66	5.62	0.00	7.84	5.24	7.0	8.02	1.5	3.1	1.00	0.29	0.00
3	16	76	10	330000.	130000.	61.52	40.41	9.63	0.91	12.24	7.60	30.0	7.71	3.0	0.4	0.00	0.00	0.00
3	16	76	11	49000.	23000.	39.11	20.48	7.02	0.00	9.94	5.96	6.5	7.58	2.0	1.4	0.00	0.00	0.00
3	16	76	12	490000.	330000.	******	42.83	8.73	0.68	11.12	8.32	16.0	7.75	3.0	2.5	4.00	0.00.	0.00
3	16	76	13	330000.	70000.	******	44.32	8.95	0.62	11.60	8.84	21.0	7.80	3.0	2.6	4.00	0.00	0.00
3	16	76	14	130000.	49000.	63.39	39.85	9.05	0.66	11.56	8.92	20.0	7.82	3.0	2.6	4.00	0.00	0.00
3	16	76	15	4000.	2000.	******	42.01	9.86	0.58	12.04	9.36	8.2	7.65	3.0	2.7	8.00	0.99	0.00
3	16	76	16	490.	330.	******	41.34	8.32	0.51	10.64	8.32	7.5	7.69	3.0	2.8	8.00	0.94	0.00
3	16	76	17	49.	0.	59.96	36.87	8.50	0.55	8.92	6.92	7.7	7.75	3.0	2.8	8.00	0.92	0.00
3	16	76	18	0.	0.	******	42.83	8.41	0.54	10.92	9.08	7.9	7.55	3.0	2.6	24.14	6.43	0.00
3	16	76	19	0.	0.	******	40.60	10.77	0.55	9.00	8.20	6.4	7.55	3.0	2.6	24.14	6.15	0.00
3	16	76	20	0.	0.	71.16	36.28	8.50	0.58	10.20	8.36	8.5	7.53	3.0	3.1	24.14	6.06	0.00
3	16	76	21	17000.	17000.	******	20.63	6.36	0.00	9.44	6.48	6.7	7.75	2.0	3.9	0.50	0.21	0.00
3	16	76	22	79000.	22000.	******	21.82	6.77	0.00	11.04	6.92	7.3	7.73	2.0	4.5	0.50	0.16	0.00
3	16	76	23	46000.	21000.	36.87	30.32	6.59	0.00	13.44	6.96	11.0	7.82	2.0	5.2	0.50	0.16	0.00
3	18	76	10	330000.	49000.	60.65	42.74	8.84	1.20	9.42	7.80	38.0	7.69	4.0	0.5	0.00	0.00	0.00
3	18	76	11	220000.	46000.	34.51	24.08	6.55	0.00	9.94	6.32	8.5	7.59	4.0	1.3	0.00	0.00	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
3	18	76	12	4900.	4900.	******	43.12	8.47	0.17	9.32	7.52	12.0	7.78	4.0	2.3	7.00	0.66	0.00
3	18	76	13	13000.	3300.	******	39.92	8.10	0.13	10.44	7.68	16.0	7.80	4.0	2.5	7.00	0.42	0.00
3	18	76	14	4600.	3300.	58.21	38.17	7.85	0.14	9.20	7.20	22.0	7.92	3.0	2.9	7.00	0.23	0.00
3	18	76	15	940.	80.	******	38.55	8.10	0.14	11.16	9.12	14.0	7.72	4.0	2.2	8.00	1.13	0.00
3	18	76	16	13.	2.	******	39.47	8.14	0.13	10.12	7.08	17.0	7.80	4.0	2.7	8.00	0.99	0.00
3	18	76	17	2.	2.	59.00	22.40	8.22	0.14	9.58	7.28	14.0	7.80	4.0	2.7	8.00	0.89	0.00
3	18	76	18	7.	7.	******	38.55	8.01	0.14	9.64	7.08	14.0	7.75	4.0	2.9	8.84	1.18	0.00
3	18	76	19	11.	4.	******	39.47	7.73	0.14	10.08	7.68	16.0	7.80	4.0	1.8	8.84	1.06	0.00
3	18	76	20	6.	2.	61.71	37.64	8.14	0.14	9.28	7.64	18.0	7.83	4.0	1.9	8.84	0.99	0.00
3	18	76	21	17000.	3300.	******	23.31	6.41	0.00	11.20	5.64	16.0	7.98	4.0	3.5	0.25	0.08	0.00
3	18	76	22	28000.	7900.	******	22.55	6.12	0.00	9.48	6.28	10.0	7.89	4.0	3.5	0.25	0.01	0.00
3	18	76	23	49000.	7000.	59.12	25.60	6.49	0.00	10.24	6.56	13.0	7.90	4.0	3.8	0.25	0.00	0.00
3	23	76	10	220000.	170000.	66.50	39.14	8.31	1.80	9.44	9.08	34.0	7.58	4.0	0.9	0.00	0.00	0.00
3	23	76	11	49000.	49000.	42.26	25.10	7.66	0.00	8.64	6.56	6.1	7.62	5.0	0.8	0.00	0.00	0.00
3	23	76	12	49000.	33000.	******	37.45	8.41	0.45	9.64	8.84	7.8	7.58	4.0	2.4	6.00	0.10	0.00
3	23	76	13	490000.	220000.	******	9.44	9.58	0.45	9.24	9.16	8.6	7.61	4.0	2.5	6.00	0.00	0.00
3	23	76	14	230000.	130000.	61.01	40.29	8.20	0.50	10.76	9.04	9.0	7.72	4.0	2.7	6.00	0.00	0.00
3	23	76	15	1300.	330.	******	38.53	8.53	0.50	8.28	8.28	9.6	7.65	4.0	2.4	7.00	0.86	0.00
3	23	76	16	79.	5.	******	29.39	8.41	0.55	8.36	8.12	8.6	7.66	4.0	2.5	7.00	0.79	0.00
3	23	76	17	31.	1.	63.62	40.29	9.83	0.56	8.64	8.40	9.6	7.73	4.0	2.8	7.00	0.79	0.00
3	23	76	18	5400.	790.	******	44.74	8.33	0.56	8.68	8.68	10.0	7.64	4.0	2.5	8.00	1.22	0.00
3	23	76	19	70.	13.	******	36.99	8.53	0.55	8.84	8.56	9.5	7.63	4.0	2.5	8.00	1.00	0.00
3	23	76	20	49.	2.	59.33	36.99	8.49	0.56	8.64	8.64	9.4	7.54	4.0	2.8	8.00	0.79	0.00
3	23	76	21	54000.	1700.	******	22.64	7.39	0.00	8.04	6.24	6.2	7.62	5.0	2.8	1.00	0.45	0.00
3	23	76	22	7000.	4600.	******	25.02	6.62	0.00	8.64	7.20	6.4	7.64	5.0	3.2	1.00	0.31	0.00
3	23	76	23	2200.	1300.	38.76	19.57	7.23	0.00	8.92	6.56	6.0	7.82	5.0	3.4	1.00	0.22	0.00
3	25	76	10	490000.	79000.	56.26	35.56	8.94	1.50	9.84	8.12	32.0	7.80	3.0	0.5	0.00	0.00	0.00
3	25	76	11	130000.	14000.	29.29	17.02	7.52	0.10	7.56	5.80	5.0	7.78	4.5	0.7	0.00	0.00	0.00
3	25	76	12	350000.	170000.	******	37.50	8.74	0.29	8.40	7.60	9.4	7.66	3.0	2.2	5.00	0.00	0.00
3	25	76	13	170000.	170000.	******	37.88	8.74	0.30	8.76	8.32	9.3	7.75	3.0	2.8	5.00	0.00	0.00
3	25	76	14	330000.	130000.	57.38	35.78	8.70	0.31	9.56	8.52	10.0	7.75	3.0	2.9	5.00	0.00	0.00
3	25	76	15	17000.	1700.	******	35.28	9.17	0.30	8.44	8.84	9.0	7.58	3.0	2.6	7.00	0.75	0.00
3	25	76	16	4600.	700.	******	34.88	8.87	0.30	8.68	7.84	9.5	7.73	3.0	2.6	7.00	0.59	0.00
3	25	76	17	490.	130.	45.38	34.88	8.96	0.35	9.20	8.08	8.6	7.72	3.0	3.0	7.00	0.59	0.00
3	25	76	18	2800.	630.	******	34.50	9.00	0.31	8.72	8.04	9.3	7.16	3.0	2.9	9.00	1.18	0.00
3	25	76	19	110.	5.	******	36.38	9.00	0.31	9.32	8.60	8.5	7.72	3.0	3.1	9.00	1.04	0.00
3	25	76	20	79.	2.	58.73	34.13	8.65	0.33	9.52	9.44	7.8	7.80	3.0	3.3	9.00	0.90	0.00
3	25	76	21	1100.	49.	******	18.23	7.39	0.00	7.12	6.00	5.6	7.68	4.5	3.2	2.00	1.51	0.00
3	25	76	22	23.	0.	******	18.38	7.70	0.00	7.84	6.32	6.6	7.85	4.5	3.6	2.00	1.42	0.00
3	25	76	23	2.	0.	28.73	16.13	7.70	0.00	7.20	5.76	5.4	7.80	4.5	3.8	2.00	1.37	0.00
3	30	76	10	790000.	170000.	62.89	38.67	9.91	1.10	11.13	9.82	32.0	7.80	4.0	0.3	0.00	0.00	0.00
3	30	76	11	8000.	2000.	35.10	23.31	8.48	0.00	7.54	5.48	4.7	8.50	4.0	0.3	0.00	0.00	0.00
3	30	76	12	17000.	7900.	******	44.00	9.71	0.37	10.04	8.92	14.0	7.55	4.0	2.7	7.00	0.79	0.00
3	30	76	13	2300.	330.	******	44.56	10.81	0.37	12.04	9.44	12.0	7.60	4.0	2.8	7.00	0.70	0.00
3	30	76	14	1700.	170.	64.66	49.81	10.00	0.37	11.32	8.56	14.0	7.62	4.0	3.2	7.00	0.51	0.00
3	30	76	15	170.	140.	******	38.56	9.95	0.37	10.92	9.16	16.0	7.50	4.0	2.9	8.00	2.57	0.00
3	30	76	16	0.	0.	******	37.95	10.00	0.36	11.20	9.36	13.0	7.46	4.0	3.1	8.00	2.48	0.00
3	30	76	17	0.	0.	63.12	40.68	10.62	0.37	10.60	8.52	16.0	7.58	4.0	3.2	8.00	2.29	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
3	30	76	18	110.	11.	******	37.80	10.05	0.36	10.12	8.60	17.0	7.52	4.0	3.0	10.00	2.76	0.00
3	30	76	19	2.	0.	******	39.32	10.14	0.38	10.68	9.48	15.0	7.50	4.0	3.4	10.00	2.59	0.00
3	30	76	20	0.	0.	62.43	38.40	8.57	0.38	11.16	9.68	17.0	7.53	4.0	3.3	10.00	2.55	0.00
3	30	76	21	790.	49.	******	18.78	9.10	0.00	6.88	5.76	7.0	7.65	4.0	2.7	1.50	0.84	0.00
3	30	76	22	110.	7.	******	23.35	8.52	0.00	7.56	5.08	7.0	7.63	4.0	3.1	1.50	0.77	0.00
3	30	76	23	11.	2.	25.32	13.99	9.71	0.00	7.48	5.52	7.0	7.72	4.0	3.2	1.50	0.70	0.00
4	1	76	10	490000.	110000.	56.70	33.29	12.09	0.70	13.40	12.24	9.7	8.50	4.0	0.5	0.00	0.00	0.00
4	1	76	11	2200.	700.	32.21	22.84	8.30	0.12	6.20	5.50	3.5	8.48	5.5	0.4	0.00	0.00	0.00
4	1	76	12	11000.	700.	******	38.05	7.78	0.27	11.12	10.32	8.5	7.90	4.0	2.5	5.00	0.63	0.00
4	1	76	13	230.	20.	******	36.10	7.57	0.25	11.00	10.96	11.0	7.82	4.0	2.6	5.00	0.61	0.00
4	1	76	14	170.	5.	54.76	48.69	8.00	0.27	11.84	11.24	12.0	7.83	4.0	2.7	5.00	0.58	0.00
4	1	76	15	230.	33.	******	33.71	8.04	0.27	12.32	11.96	8.5	7.77	4.0	2.8	6.00	2.08	0.00
4	1	76	16	0.	0.	******	38.28	10.91	0.27	12.08	11.52	9.6	7.72	4.0	2.8	6.00	2.06	0.00
4	1	76	17	0.	0.	56.26	46.97	9.26	0.26	11.56	11.28	9.4	7.72	4.0	3.2	6.00	2.01	0.00
4	1	76	18	130.	33.	******	33.26	14.35	0.27	11.28	11.28	9.5	7.83	4.0	3.4	7.00	1.90	0.00
4	1	76	19	0.	0.	******	37.45	9.22	0.25	11.00	10.60	9.2	7.78	4.0	3.5	7.00	1.75	0.00
4	1	76	20	0.	0.	54.31	34.16	9.35	0.25	11.40	11.40	8.8	7.79	4.0	3.5	7.00	1.50	0.00
4	1	76	21	790.	130.	******	28.46	9.65	0.10	5.28	5.28	4.4	7.33	5.5	3.2	1.00	0.30	0.00
4	1	76	22	170.	45.	******	21.72	8.09	0.00	5.44	5.12	4.3	7.32	5.5	3.4	1.00	0.08	0.00
4	1	76	23	49.	33.	35.96	22.85	8.17	0.00	5.84	4.44	3.8	7.80	5.5	3.6	1.00	0.03	0.00
4	6	76	10	49000.	49000.	69.30	35.29	5.33	1.20	31.95	29.68	8.0	8.10	5.0	2.1	0.00	0.00	0.00
4	6	76	11	13000.	13000.	28.87	24.62	6.71	0.00	8.48	8.12	4.3	8.76	7.0	1.5	0.00	0.00	0.00
4	6	76	12	11000.	4900.	******	32.53	6.97	0.17	26.30	23.85	9.1	7.82	5.0	3.6	3.00	0.15	0.00
4	6	76	13	79000.	7000.	******	21.34	6.20	0.19	23.87	22.58	5.6	7.84	5.0	3.9	3.00	0.00	0.00
4	6	76	14	17000.	11000.	60.72	26.11	6.63	0.22	26.55	25.00	10.0	7.81	5.0	3.9	3.00	0.00	0.00
4	6	76	15	9.	0.	******	25.81	5.57	0.15	23.12	22.04	8.3	7.75	5.5	3.3	5.00	3.20	0.25
4	6	76	16	0.	0.	******	28.05	5.95	0.16	22.76	21.04	10.0	7.79	5.5	3.7	5.00	3.02	0.00
4	6	76	17	0.	0.	62.22	24.32	7.05	0.18	21.32	20.56	13.0	7.80	5.5	3.8	5.00	2.95	0.00
4	6	76	18	13.	13.	******	22.68	5.82	0.16	23.06	21.70	12.0	7.80	5.5	4.1	4.00	1.52	0.00
4	6	76	19	2.	0.	******	22.08	6.25	0.16	22.29	21.67	11.0	7.89	5.5	3.8	4.00	1.32	0.00
4	6	76	20	1.	0.	61.62	20.59	7.10	0.16	21.08	20.88	8.0	7.92	5.5	4.1	4.00	1.17	0.00
4	6	76	21	2200.	700.	******	20.59	6.20	0.00	8.84	7.36	5.0	7.61	7.0	3.5	1.00	0.20	0.00
4	6	76	22	790.	170.	******	22.83	5.52	0.00	9.48	8.76	6.2	7.86	7.0	4.1	1.00	0.15	0.00
4	6	76	23	230.	23.	33.79	19.10	5.82	0.00	8.08	8.32	4.2	7.65	7.0	4.1	1.00	0.12	0.00
4	8	76	10	49000.	49000.	62.02	25.38	6.01	0.69	22.20	20.18	8.1	8.67	5.5	1.9	0.00	0.00	0.00
4	8	76	11	4900.	1100.	31.71	19.29	5.36	0.10	8.48	7.08	3.8	8.58	8.0	0.8	0.00	0.00	0.00
4	8	76	12	17000.	17000.	******	26.34	7.93	0.21	19.70	19.10	11.0	8.14	6.0	3.3	3.00	0.33	0.00
4	8	76	13	140000.	94000.	******	24.26	6.01	0.22	20.80	18.95	8.8	8.05	6.0	3.4	3.00	0.20	0.00
4	8	76	14	33000.	23000.	59.35	24.26	7.12	0.21	20.26	20.10	8.9	8.13	6.0	3.7	3.00	0.00	0.00
4	8	76	15	24000.	3300.	******	27.30	5.53	0.23	19.35	15.95	9.2	8.03	6.0	3.6	2.00	0.30	0.00
4	8	76	16	7900.	460.	******	28.85	6.39	0.22	18.32	17.53	15.0	8.10	6.0	3.7	2.00	0.25	0.00
4	8	76	17	17000.	79.	57.12	26.26	6.39	0.22	17.56	16.28	9.0	8.08	6.0	4.0	2.00	0.20	0.00
4	8	76	18	3500.	790.	******	26.93	6.06	0.21	20.28	18.84	11.0	8.09	6.0	4.6	3.50	0.98	0.00
4	8	76	19	2400.	33.	******	27.15	6.64	0.25	17.48	16.00	12.0	8.10	6.0	4.3	3.50	0.78	0.00
4	8	76	20	1300.	17.	60.98	29.15	7.12	0.27	18.38	17.43	8.6	8.10	6.0	4.5	3.50	0.58	0.00
4	8	76	21	330.	230.	******	17.95	6.01	0.00	7.60	6.76	4.0	7.98	8.0	3.6	0.50	0.05	0.00
4	8	76	22	1100.	110.	******	19.07	6.15	0.00	7.24	6.56	4.5	7.90	8.0	3.7	0.50	0.00	9.00
4	8	76	23	330.	35.	32.05	19.73	5.63	0.00	7.48	6.40	4.1	8.01	8.0	4.2	0.50	0.00	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
4	13	76	10	22000.	2000.	53.86	23.23	4.80	0.00	20.77	18.10	8.3	7.90	10.0	0.4	0.00	0.00	0.00
4	13	76	11	220.	20.	31.03	18.64	3.83	0.00	7.00	6.76	3.3	7.63	10.5	2.3	0.00	0.00	0.00
4	13	76	12	700.	80.	******	26.57	5.90	0.00	18.80	17.14	7.4	7.77	10.0	2.7	3.00	0.80	0.00
4	13	76	13	20.	20.	******	21.74	5.35	0.00	17.34	17.14	7.3	7.82	10.0	2.7	3.00	0.60	0.00
4	13	76	14	20.	5.	50.08	21.74	5.12	0.00	18.47	16.65	7.3	7.91	10.0	3.0	3.00	0.55	0.00
4	13	76	15	170.	20.	******	17.55	5.25	0.00	19.87	16.60	8.2	7.89	11.0	2.7	1.00	0.55	0.00
4	13	76	16	80.	20.	******	22.73	4.26	0.00	17.67	16.72	8.1	7.87	11.0	2.6	1.00	0.45	0.00
4	13	76	17	40.	17.	53.13	24.15	4.57	0.00	18.00	16.53	8.0	7.95	11.0	2.9	1.00	0.40	0.00
4	13	76	18	230.	20.	******	18.52	5.70	0.00	18.06	16.46	8.2	7.90	11.0	3.1	2.00	1.05	0.00
4	13	76	19	23.	2.	******	13.04	4.10	0.00	16.74	15.58	8.7	7.93	11.0	3.2	2.00	0.95	0.00
4	13	76	20	7.	1.	53.78	25.51	4.53	0.00	17.13	16.26	9.0	7.92	11.0	3.4	2.00	0.90	0.00
4	13	76	21	230.	20.	******	19.32	4.61	0.00	5.52	5.52	3.5	7.71	11.0	3.6	0.75	0.15	0.00
4	13	76	22	80.	20.	******	17.55	4.92	0.00	6.84	6.84	3.8	7.72	11.0	3.8	0.75	0.05	0.00
4	13	76	23	50.	5.	32.20	16.91	5.86	0.00	7.24	6.64	3.7	7.82	11.0	4.4	0.75	0.00	0.00
4	15	76	10	8000.	2000.	58.59	18.51	4.76	0.00	24.33	19.33	8.3	8.03	11.0	3.1	0.00	0.00	0.00
4	15	76	11	170.	20.	23.82	14.97	3.76	0.00	4.20	4.20	2.2	7.72	10.0	2.2	0.00	0.00	0.00
4	15	76	12	1100.	33.	******	21.41	4.05	0.00	20.07	17.33	7.7	8.00	11.0	4.1	2.00	0.90	0.00
4	15	76	13	220.	11.	******	25.59	4.37	0.00	17.36	17.36	7.4	8.13	11.0	4.2	2.00	0.83	0.00
4	15	76	14	79.	0.	46.20	19.80	3.84	0.00	17.95	17.10	6.9	8.16	11.0	4.5	2.00	0.75	0.00
4	15	76	15	79.	4.	******	18.90	4.13	0.00	17.32	15.14	8.1	8.12	11.0	3.9	1.00	1.25	0.00
4	15	76	16	8.	0.	******	22.13	4.17	0.00	20.68	16.74	8.2	8.12	11.0	4.2	1.00	1.15	0.00
4	15	76	17	7.	0.	50.22	22.13	3.72	0.00	19.94	16.84	7.8	8.12	11.0	4.4	1.00	1.05	0.00
4	15	76	18	13.	0.	******	16.60	4.09	0.00	19.94	17.24	8.2	8.08	11.0	4.2	3.00	2.33	0.00
4	15	76	19	0.	0.	******	22.86	3.72	0.00	21.07	17.40	8.2	8.12	11.0	3.9	3.00	2.30	0.00
4	15	76	20	0.	0.	51.99	11.99	3.52	0.00	20.55	17.13	7.8	8.02	11.0	4.5	3.00	2.25	0.00
4	15	76	21	22.	0.	******	26.08	3.31	0.00	4.16	3.98	2.2	7.75	10.0	4.0	1.00	0.83	0.00
4	15	76	22	17.	0.	******	18.51	2.94	0.00	4.04	3.72	2.2	7.73	10.0	4.1	1.00	0.80	0.00
4	15	76	23	17.	0.	27.85	17.70	2.98	0.00	4.32	4.12	2.5	7.30	10.0	4.1	1.00	0.80	0.00
4	20	76	10	500.	200.	67.19	20.04	3.16	0.00	31.50	29.15	7.5	8.85	10.0	15.8	0.00	0.00	0.00
4	20	76	11	240.	5.	30.38	18.08	2.78	0.00	10.50	9.22	4.0	7.85	8.0	5.1	0.00	0.00	0.00
4	20	76	12	110.	7.	******	20.12	3.24	0.00	31.93	28.29	8.7	7.95	11.5	11.6	0.50	0.25	0.00
4	20	76	13	33.	5.	******	21.64	2.87	0.00	27.39	27.39	8.0	7.90	11.5	13.2	0.50	0.17	0.00
4	20	76	14	20.	1.	60.60	19.32	2.99	0.00	30.43	27.29	8.8	7.90	10.5	10.8	0.50	0.08	0.00
4	20	76	15	70.	2.	******	20.92	3.37	0.00	32.12	28.79	7.7	7.93	10.0	6.6	1.00	0.14	0.00
4	20	76	16	33.	0.	******	20.12	2.95	0.00	30.79	26.78	9.2	7.90	11.0	9.0	1.00	0.03	0.00
4	20	76	17	33.	0.	60.20	22.36	2.65	0.00	26.92	24.95	7.8	7.90	10.5	10.6	1.00	0.00	0.00
4	20	76	18	17.	0.	******	25.07	3.16	0.00	25.98	23.84	5.2	7.80	10.5	7.8	2.00	1.20	0.00
4	20	76	19	2.	0.	******	19.08	3.29	0.00	27.56	22.99	8.2	7.75	10.5	8.8	2.00	1.12	0.00
4	20	76	20	1.	1.	57.49	21.72	3.24	0.00	28.05	23.54	7.6	7.75	10.0	6.5	2.00	1.03	0.00
4	20	76	21	49.	0.	******	15.33	3.12	0.00	10.20	9.32	3.8	7.40	10.0	5.5	0.50	0.11	0.00
4	20	76	22	110.	0.	******	16.85	2.74	0.00	10.12	9.16	4.1	7.42	10.0	5.6	0.50	0.08	0.00
4	20	76	23	49.	0.	28.90	16.93	2.36	0.00	10.16	9.12	4.0	7.45	9.0	5.7	0.50	0.03	0.00
4	22	76	10	16000.	1300.	57.35	29.46	1.33	0.00	17.54	16.38	6.6	9.12	12.0	10.2	0.00	0.00	0.00
4	22	76	11	280.	2.	34.43	16.06	2.71	0.00	11.80	10.46	4.5	8.18	12.0	4.3	0.00	0.00	0.00
4	22	76	12	5400.	1100.	******	27.42	1.54	0.00	11.32	10.48	6.2	9.00	12.0	8.1	1.00	0.87	0.00
4	22	76	13	1300.	240.	******	26.48	1.50	0.00	16.92	15.52	6.2	9.05	12.0	7.9	1.00	0.76	0.00
4	22	76	14	450.	94.	50.92	27.18	1.54	0.00	16.48	15.84	5.8	9.00	12.0	8.0	1.00	0.70	0.00
4	22	76	15	3100.	490.	******	28.05	3.27	0.00	17.12	15.52	6.6	9.00	12.0	7.2	3.00	1.18	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
4	22	76	16	330.	79.	******	20.90	3.65	0.00	16.56	15.48	6.1	9.05	12.0	8.8	3.00	1.04	0.00
4	22	76	17	110.	49.	49.93	24.99	2.35	0.00	16.52	15.52	6.3	9.00	12.0	9.5	3.00	0.98	0.00
4	22	76	18	140.	31.	******	27.42	1.69	0.00	16.12	15.92	5.9	8.92	12.0	7.8	5.00	2.89	0.00
4	22	76	19	0.	0.	******	24.68	1.08	0.00	16.43	15.24	6.5	8.93	12.0	7.9	5.00	2.70	0.00
4	22	76	20	0.	0.	54.94	27.26	1.31	0.00	15.68	14.44	6.4	8.95	12.0	9.2	5.00	2.61	0.00
4	22	76	21	180.	1.	******	16.90	2.73	0.00	16.40	14.56	4.5	8.20	11.0	5.1	0.50	0.11	0.00
4	22	76	22	170.	13.	******	17.23	3.39	0.00	12.88	10.84	5.1	8.23	11.0	5.6	0.50	0.00	0.00
4	22	76	23	110.	7.	40.66	16.45	2.58	0.00	13.04	11.44	5.1	8.23	11.0	6.2	0.50	0.00	0.00
4	27	76	10	54000.	7900.	68.51	31.79	1.69	0.00	24.92	23.88	6.2	8.62	9.5	6.6	0.00	0.00	0.00
4	27	76	11	490.	2.	30.40	18.30	1.02	0.00	25.12	23.68	7.2	8.30	6.5	7.2	0.00	0.00	0.00
4	27	76	12	9200.	1700.	******	26.60	1.54	0.00	21.84	21.40	6.4	8.47	9.0	6.9	0.50	0.39	0.00
4	27	76	13	5400.	1300.	******	31.02	1.65	0.00	23.24	21.84	6.8	8.53	9.0	6.6	0.50	0.33	0.00
4	27	76	14	16000.	1400.	57.54	30.63	1.34	0.00	23.52	21.40	7.0	8.52	9.0	7.8	0.50	0.22	0.00
4	27	76	15	24000.	1600.	******	29.86	1.65	0.00	22.72	20.88	6.7	8.47	9.0	5.8	2.00	1.67	0.00
4	27	76	16	460.	230.	******	35.91	1.97	0.00	22.24	20.64	6.3	8.47	9.0	6.8	2.00	1.56	0.00
4	27	76	17	130.	17.	60.80	30.01	1.34	0.00	20.96	20.56	6.7	8.51	9.0	7.9	2.00	1.39	0.00
4	27	76	18	9200.	1300.	******	37.84	1.61	0.00	22.48	20.76	6.9	8.51	9.0	7.4	1.00	0.67	0.00
4	27	76	19	3500.	790.	******	32.11	1.50	0.00	21.80	20.40	6.3	8.52	9.0	6.4	1.00	0.61	0.00
4	27	76	20	2400.	170.	53.51	26.75	1.38	0.00	22.52	20.44	7.0	8.53	9.0	8.2	1.00	0.50	0.00
4	27	76	21	700.	13.	******	16.67	0.95	0.00	17.84	12.68	7.7	8.28	6.5	8.4	0.75	0.44	0.00
4	27	76	22	790.	13.	******	15.20	1.06	0.00	16.00	11.44	6.9	8.30	6.5	8.5	0.75	0.39	0.00
4	27	76	23	230.	5.	28.31	12.72	0.67	0.00	15.80	11.68	6.7	8.29	6.5	8.8	0.75	0.33	0.00
4	29	76	10	17000.	7900.	62.91	27.62	1.29	0.00	21.88	20.04	8.4	8.90	12.0	9.8	0.00	0.00	0.00
4	29	76	11	220.	2.	31.62	13.01	0.57	0.00	17.16	16.14	6.8	8.65	10.0	7.1	0.00	0.00	0.00
4	29	76	12	11000.	3300.	******	29.54	1.40	0.00	20.28	18.60	6.9	8.83	12.0	7.3	0.50	0.17	0.00
4	29	76	13	11000.	3300.	******	25.23	1.40	0.00	19.04	17.88	6.4	8.82	11.0	8.9	0.50	0.03	0.00
4	29	76	14	7900.	1700.	56.37	27.15	1.27	0.00	19.64	17.32	9.0	8.85	11.0	8.3	0.50	0.00	0.00
4	29	76	15	4900.	460.	******	43.19	1.12	0.00	19.32	17.52	8.1	8.80	12.0	8.1	1.00	0.86	0.00
4	29	76	16	330.	230.	******	30.82	1.34	0.00	18.72	17.20	7.5	8.77	12.0	7.4	1.00	0.78	0.00
4	29	76	17	100.	110.	54.77	29.86	1.36	0.00	20.02	17.04	8.7	8.80	12.0	8.3	1.00	0.72	0.00
4	29	76	18	1300.	330.	******	27.63	1.36	0.00	18.80	16.84	6.9	8.75	12.0	6.9	2.00	1.33	0.00
4	29	76	19	230.	130.	******	26.51	1.21	0.00	17.84	16.40	7.9	8.75	12.0	8.1	2.00	1.28	0.00
4	29	76	20	170.	9.	55.01	31.46	2.02	0.00	17.72	16.32	7.2	8.80	12.0	8.4	2.00	1.14	0.00
4	29	76	21	110.	13.	******	14.85	0.68	0.00	15.19	7.88	5.8	8.51	10.0	6.5	1.00	0.53	0.00
4	29	76	22	49.	23.	******	11.66	0.48	0.00	12.75	11.80	4.8	8.55	10.0	6.5	1.00	0.47	0.00
4	29	76	23	33.	8.	32.18	16.77	0.79	0.00	14.40	13.00	5.1	8.60	10.0	6.8	1.00	0.42	0.00
5	4	76	10	4600.	200.	95.61	33.83	0.82	0.00	41.24	38.27	12.0	8.07	14.0	11.8	0.00	0.00	0.00
5	4	76	11	23.	7.	22.91	16.65	0.17	0.00	5.04	4.08	2.7	8.05	15.0	7.1	0.00	0.00	0.00
5	4	76	12	2300.	230.	******	33.37	0.72	0.00	35.29	32.24	12.0	8.12	14.0	7.5	1.00	0.46	0.00
5	4	76	13	3300.	170.	******	33.91	0.76	0.00	36.28	31.59	12.0	8.10	14.0	8.3	1.00	0.29	0.00
5	4	76	14	1100.	130.	93.09	34.80	0.76	0.00	35.33	32.00	13.0	8.10	14.0	9.5	1.00	0.17	0.00
5	4	76	15	1100.	130.	******	33.52	0.78	0.00	35.06	31.56	12.0	8.11	14.0	8.0	2.00	1.44	0.00
5	4	76	16	790.	110.	******	34.29	0.72	0.00	34.60	30.60	12.0	8.10	14.0	9.3	2.00	1.26	0.00
5	4	76	17	300.	49.	67.89	38.72	0.71	0.00	33.19	29.75	13.0	8.10	14.0	9.3	2.00	1.21	0.00
5	4	76	18	1700.	23.	******	13.67	0.74	0.00	33.80	30.67	12.0	9.15	14.0	9.0	3.00	2.07	0.00
5	4	76	19	330.	13.	******	35.82	0.72	0.00	33.18	28.71	13.0	9.13	14.0	9.6	3.00	1.84	0.00
5	4	76	20	230.	11.	67.20	36.72	0.74	0.00	35.31	30.94	13.0	9.12	14.0	9.6	3.00	1.72	0.00
5	4	76	21	17.	0.	******	19.47	0.24	0.00	4.76	4.32	3.2	9.28	15.0	6.7	1.50	0.78	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
5	4	76	22	13.	0.	******	17.33	0.97	0.00	5.12	4.44	3.0	9.27	15.0	6.6	1.50	0.72	0.00
5	4	76	23	13.	0.	20.47	24.29	1.03	0.00	5.20	4.48	3.3	9.25	15.0	7.4	1.50	0.63	0.00
5	6	76	10	13000.	2300.	88.61	30.21	0.42	0.00	41.12	37.44	11.0	8.32	15.0	12.4	0.00	0.00	0.00
5	6	76	11	70.	9.	21.84	13.22	0.15	0.00	3.70	3.32	2.8	8.25	14.5	7.1	0.00	0.00	0.00
5	6	76	12	490.	130.	******	34.62	0.39	0.00	31.95	28.54	12.0	8.50	15.0	9.3	2.00	1.78	0.00
5	6	76	13	1300.	140.	******	33.77	0.35	0.00	31.52	22.56	11.0	8.28	15.0	9.7	2.00	1.67	0.00
5	6	76	14	490.	70.	74.67	35.79	0.35	0.00	31.59	27.81	11.0	8.32	15.0	9.5	2.00	1.61	0.00
5	6	76	15	80.	20.	******	36.79	0.38	0.00	29.85	26.62	11.0	8.35	15.0	7.0	3.00	2.25	0.00
5	6	76	16	49.	13.	******	28.66	0.55	0.00	31.27	28.13	12.0	8.28	15.0	9.2	3.00	2.17	0.00
5	6	76	17	33.	5.	90.32	33.00	0.49	0.00	31.00	28.53	12.0	8.36	15.0	9.2	3.00	2.14	0.00
5	6	76	18	22.	0.	******	34.82	0.25	0.00	31.53	28.73	12.0	8.30	15.0	7.6	5.00	2.94	0.04
5	6	76	19	0.	0.	******	32.92	0.30	0.00	28.53	27.00	14.0	8.34	15.0	6.9	5.00	2.83	0.00
5	6	76	20	0.	0.	77.38	35.01	0.35	0.00	29.50	26.00	11.0	8.32	15.0	9.9	5.00	2.72	0.00
5	6	76	21	0.	0.	******	15.10	0.03	0.00	3.64	3.44	2.7	8.34	14.5	5.6	2.00	1.19	0.35
5	6	76	22	0.	0.	******	15.96	0.08	0.00	3.56	2.96	2.5	8.37	14.5	6.0	2.00	1.00	0.22
5	6	76	23	0.	0.	18.44	16.73	0.04	0.00	3.88	3.88	2.5	8.35	14.5	6.8	2.00	0.81	0.12
5	11	76	10	35000.	13000.	86.21	37.34	0.79	0.00	38.93	34.63	15.0	9.35	16.0	10.5	0.00	0.00	0.00
5	11	76	11	3500.	490.	28.49	24.18	0.14	0.00	5.92	2.80	4.3	9.11	16.5	5.6	0.00	0.00	0.00
5	11	76	12	5400.	790.	******	35.08	1.01	0.00	33.89	29.94	16.0	9.37	16.0	8.2	2.00	1.74	0.00
5	11	76	13	3500.	170.	******	36.66	1.01	0.00	33.31	27.38	15.0	9.40	16.0	8.7	2.00	1.63	0.00
5	11	76	14	1700.	170.	80.13	37.41	0.98	0.00	32.60	28.33	14.0	9.30	16.0	8.0	2.00	1.57	0.00
5	11	76	15	330.	130.	******	40.41	1.03	0.00	31.87	27.94	15.0	9.45	16.0	4.4	4.00	3.46	0.00
5	11	76	16	49.	8.	******	67.39	0.90	0.00	31.67	27.67	16.0	9.37	16.0	8.4	4.00	3.34	0.00
5	11	76	17	49.	0.	76.99	40.25	0.97	0.00	30.45	25.96	15.0	9.30	16.0	7.9	4.00	3.23	0.00
5	11	76	18	5.	0.	******	37.41	0.74	0.00	31.80	26.47	15.0	9.26	16.0	7.3	9.92	5.48	0.24
5	11	76	19	0.	0.	******	40.11	0.70	0.00	31.87	26.32	15.0	9.25	16.0	8.1	9.92	4.86	0.06
5	11	76	20	0.	0.	71.51	40.41	0.60	0.00	31.40	26.20	15.0	9.23	16.0	7.8	9.92	4.29	0.03
5	11	76	21	8.	0.	******	23.17	0.15	0.00	5.60	4.12	4.5	9.18	16.5	4.7	2.00	1.11	0.00
5	11	76	22	11.	0.	******	24.44	0.16	0.00	5.72	4.00	4.6	9.18	16.5	4.9	2.00	1.06	0.00
5	11	76	23	11.	0.	32.16	25.41	0.17	0.00	6.00	4.08	4.6	9.17	16.5	6.1	2.00	1.00	0.00
5	13	76	10	170000.	23000.	96.34	41.08	1.41	0.00	30.12	25.16	20.0	9.20	15.0	6.9	0.00	0.00	0.00
5	13	76	11	4900.	700.	30.97	24.21	0.31	0.00	10.32	6.84	7.0	9.00	15.0	5.2	0.00	0.00	0.00
5	13	76	12	35000.	13000.	******	36.30	1.48	0.00	27.19	22.08	20.0	9.20	15.0	5.0	1.00	0.65	0.00
5	13	76	13	17000.	13000.	******	33.37	1.54	0.00	30.50	24.31	19.0	9.20	15.0	5.6	1.00	0.55	0.00
5	13	76	14	17000.	4900.	77.86	39.36	1.43	0.00	28.77	23.57	20.0	9.20	15.0	6.3	1.00	0.52	0.00
5	13	76	15	16000.	1100.	******	41.25	1.47	0.00	28.80	22.47	15.0	9.15	15.0	5.7	3.00	2.46	0.00
5	13	76	16	9200.	330.	******	36.88	1.36	0.00	26.25	20.81	19.0	9.18	15.0	5.6	3.00	2.38	0.00
5	13	76	17	790.	79.	72.19	37.33	1.49	0.00	26.06	21.90	20.0	9.19	15.0	6.3	3.00	2.35	0.00
5	13	76	18	17.	2.	******	40.62	0.61	0.00	25.93	21.07	17.0	8.75	15.0	5.3	19.48	5.83	0.25
5	13	76	19	2.	0.	******	39.05	0.59	0.00	27.56	21.63	18.0	8.80	15.0	5.9	19.48	5.12	0.04
5	13	76	20	2.	0.	76.32	39.20	0.63	0.00	27.33	23.20	19.0	8.80	15.0	6.2	19.48	4.81	0.00
5	13	76	21	1300.	220.	******	28.42	0.33	0.00	6.68	5.12	7.0	9.02	15.0	4.4	1.00	0.64	0.00
5	13	76	22	700.	49.	******	29.10	0.31	0.00	6.88	5.44	6.1	9.05	15.0	4.6	1.00	0.52	0.00
5	13	76	23	250.	49.	35.46	25.36	0.35	0.00	6.28	5.40	5.7	9.01	15.0	4.8	1.00	0.50	0.00
5	18	76	10	49000.	17000.	147.13	45.41	4.32	0.00	27.49	23.44	18.0	7.93	17.5	3.8	0.00	0.00	0.00
5	18	76	11	160000.	4900.	36.46	29.47	1.91	0.00	6.36	5.36	4.2	8.13	17.5	3.8	0.00	0.00	0.00
5	18	76	12	11000.	700.	******	49.04	4.56	0.00	21.32	19.04	17.0	8.31	17.0	3.9	3.00	1.57	0.00
5	18	76	13	2300.	490.	******	47.65	4.15	0.00	24.15	19.84	15.0	8.29	17.0	3.6	3.00	1.40	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
5	18	76	14	1100.	20.	108.25	40.09	4.39	0.00	24.56	20.84	15.0	8.32	17.0	4.1	3.00	1.24	0.00
5	18	76	15	220.	0.	******	49.79	3.30	0.00	22.85	19.80	15.0	7.89	17.0	3.4	19.48	17.75	0.00
5	18	76	16	0.	0.	******	46.43	3.96	0.00	20.54	17.50	14.0	7.73	17.0	3.7	19.48	17.52	0.00
5	18	76	17	0.	0.	86.34	63.68	3.28	0.00	20.15	16.90	15.0	7.82	17.0	4.3	19.48	17.30	0.00
5	18	76	18	700.	130.	******	47.93	4.08	0.00	20.65	17.40	14.0	8.34	17.0	3.8	4.00	2.42	0.00
5	18	76	19	49.	5.	******	47.74	4.20	0.00	17.95	16.25	14.0	8.32	17.0	4.0	4.00	2.30	0.00
5	18	76	20	25.	3.	162.98	43.96	4.03	0.00	18.76	16.34	15.0	8.32	17.0	4.4	4.00	2.19	0.00
5	18	76	21	1700.	490.	******	34.13	1.67	0.00	5.56	4.80	4.2	8.18	17.5	4.3	2.00	1.40	0.00
5	18	76	22	140.	2.	******	31.14	1.65	0.00	5.68	4.76	4.1	8.17	17.5	3.7	2.00	1.29	0.00
5	18	76	23	8.	2.	32.26	26.48	1.69	0.00	5.80	5.12	4.0	8.28	17.5	4.8	2.00	1.18	0.00
5	20	76	10	49000.	5000.	87.73	43.21	4.66	0.00	39.73	34.13	21.0	8.72	16.5	4.3	0.00	0.00	0.00
5	20	76	11	17000.	2000.	24.66	21.23	1.72	0.00	9.60	5.37	3.4	8.23	13.5	4.4	0.00	0.00	0.00
5	20	76	12	49000.	1400.	******	36.35	4.50	0.00	30.68	26.05	17.0	8.22	16.5	4.3	1.00	0.53	0.00
5	20	76	13	23000.	2300.	******	38.17	4.62	0.00	29.78	25.17	20.0	8.23	16.0	4.1	1.00	0.44	0.00
5	20	76	14	17000.	1100.	77.98	50.39	4.42	0.00	28.73	24.67	19.0	8.32	16.0	5.0	1.00	0.39	0.00
5	20	76	15	13.	0.	******	39.16	4.06	0.00	31.40	27.00	20.0	7.92	16.5	4.1	9.92	9.39	0.00
5	20	76	16	8.	0.	******	38.17	4.20	0.00	29.47	25.13	18.0	7.93	16.0	5.0	9.92	9.17	0.00
5	20	76	17	8.	0.	78.89	42.05	4.12	0.00	28.90	23.95	19.0	8.02	16.0	5.3	9.92	9.00	0.00
5	20	76	18	1100.	94.	******	38.08	4.02	0.00	35.67	29.27	18.0	8.11	16.5	4.5	4.00	2.42	0.00
5	20	76	19	130.	5.	******	41.06	4.06	0.00	37.73	27.60	20.0	8.08	16.0	4.3	4.00	2.33	0.00
5	20	76	20	130.	5.	99.38	42.09	4.06	0.00	30.73	26.67	18.0	8.31	16.0	5.1	4.00	2.25	0.00
5	20	76	21	170.	23.	******	21.73	1.69	0.00	5.52	5.04	3.8	8.21	18.0	4.3	1.50	1.06	0.00
5	20	76	22	920.	11.	******	23.30	1.95	0.00	5.12	5.12	3.6	8.13	18.0	5.0	1.50	0.94	0.00
5	20	76	23	240.	0.	24.12	24.54	1.70	0.00	5.20	4.64	4.8	8.24	18.0	5.0	1.50	0.89	0.00
5	20	76	10	130000.	8000.	******	59.48	4.70	0.00	115.27	101.87	25.0	8.28	19.0	3.7	0.00	0.00	0.00
5	20	76	12	170000.	7000.	******	54.48	4.22	0.00	36.60	30.80	20.0	8.22	18.5	3.9	2.00	0.61	0.00
5	20	76	13	17000.	110.	******	57.17	4.10	0.00	34.07	29.47	21.0	8.15	18.5	3.9	2.00	0.53	0.00
5	20	76	14	3300.	80.	110.70	56.84	4.08	0.00	35.67	29.20	20.0	8.22	18.5	4.5	2.00	0.47	0.00
5	20	76	15	230.	20.	******	49.73	3.70	0.00	34.37	29.00	20.0	7.80	18.0	3.7	14.88	14.19	0.00
5	20	76	16	130.	2.	******	44.61	3.70	0.00	40.40	35.87	20.0	7.78	18.0	3.5	14.88	13.74	0.00
5	20	76	17	130.	2.	99.30	53.70	4.00	0.00	41.07	27.60	18.0	7.90	18.0	4.7	14.88	13.63	0.00
5	20	76	18	79.	23.	******	56.34	3.62	0.00	39.13	32.67	19.0	8.07	18.0	4.0	5.00	2.82	0.00
5	20	76	19	79.	2.	******	59.98	3.68	0.00	32.27	25.80	18.0	8.12	18.0	4.1	5.00	2.74	0.00
5	20	76	20	79.	0.	99.13	57.50	4.10	0.00	21.87	24.53	18.0	8.13	18.0	4.7	5.00	2.68	0.00
5	25	76	10	180000.	2000.	49.56	12.68	3.29	0.00	46.73	40.45	22.0	8.28	17.0	5.5	0.00	0.00	0.00
5	25	76	11	46000.	1400.	1.52	******	1.12	0.00	6.16	6.16	4.5	8.12	18.0	4.6	0.00	0.00	0.00
5	25	76	12	3500.	350.	******	11.09	3.63	0.00	39.60	29.53	20.0	8.11	17.0	6.7	5.00	2.68	0.00
5	25	76	13	330.	2.	******	8.21	3.89	0.00	40.80	34.27	18.0	8.27	17.0	6.2	5.00	2.51	0.00
5	25	76	14	330.	2.	66.67	13.40	3.50	0.00	38.33	33.73	20.0	8.20	17.0	7.0	5.00	2.32	0.00
5	25	76	15	7900.	1700.	******	33.25	3.44	0.00	41.00	35.33	15.0	8.24	17.0	4.6	2.00	1.50	0.00
5	25	76	16	1300.	2.	******	37.40	3.20	0.00	43.27	36.60	18.0	8.20	17.0	5.0	2.00	1.38	0.00
5	25	76	17	700.	2.	90.03	33.81	3.73	0.00	34.20	31.93	15.0	8.28	17.0	5.4	2.00	1.27	0.00
5	25	76	18	4900.	330.	******	26.06	3.48	0.00	21.76	21.76	15.0	8.19	17.0	5.1	3.00	1.81	0.00
5	25	76	19	280.	22.	******	36.44	3.36	0.00	44.00	33.32	19.0	8.17	17.0	5.7	3.00	1.67	0.00
5	25	76	20	250.	22.	73.04	10.93	3.34	0.00	45.13	30.80	15.0	8.26	17.0	6.1	3.00	1.58	0.00
5	25	76	21	490.	11.	******	******	1.23	0.00	5.96	4.88	4.6	8.19	18.0	4.1	2.00	1.33	0.00
5	25	76	22	130.	2.	******	******	1.15	0.00	5.80	4.92	3.8	8.03	18.0	4.5	2.00	1.27	0.00
5	25	76	23	11.	2.	******	******	1.31	0.00	5.80	4.60	4.2	8.32	18.0	5.7	2.00	1.21	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
5	27	76	10	79000.	79000.	99.84	37.74	2.62	0.00	48.88	43.59	20.0	8.92	17.0	11.0	0.00	0.00	0.00
5	27	76	11	54000.	260.	24.84	12.70	0.97	0.00	5.32	5.32	3.1	8.19	17.0	6.0	0.00	0.00	0.00
5	27	76	12	2300.	2300.	******	31.51	3.13	0.00	43.10	37.15	20.0	8.68	17.0	7.3	3.00	1.18	0.00
5	27	76	13	9200.	1100.	******	31.67	2.54	0.00	41.87	37.00	20.0	8.68	17.0	7.0	3.00	1.04	0.00
5	27	76	14	4900.	200.	91.43	36.43	2.94	0.00	40.93	35.93	18.0	8.67	17.0	8.9	3.00	0.93	0.00
5	27	76	15	9.	0.	******	36.98	1.40	0.00	37.07	32.87	20.0	7.98	17.0	8.0	20.00	13.15	0.00
5	27	76	16	2.	0.	******	35.48	1.29	0.00	32.80	32.47	20.0	7.88	17.0	7.4	20.00	12.81	0.00
5	27	76	17	1.	0.	86.19	35.63	1.96	0.00	43.13	33.40	20.0	7.98	17.0	8.9	20.00	12.47	0.00
5	27	76	18	170.	5.	******	33.10	2.38	0.00	38.53	34.13	18.0	8.55	17.0	7.8	4.00	2.92	0.00
5	27	76	19	230.	5.	******	34.13	2.65	0.00	39.67	27.87	20.0	8.55	17.0	7.2	4.00	2.78	0.00
5	27	76	20	68.	5.	87.62	37.06	2.35	0.00	38.40	27.60	18.0	8.58	17.0	8.5	4.00	2.72	0.00
5	27	76	21	0.	0.	******	15.79	0.33	0.00	4.08	3.72	2.7	7.79	17.0	5.0	20.00	13.27	11.01
5	27	76	22	0.	0.	******	18.17	0.50	0.00	4.24	4.00	2.9	7.76	17.0	5.4	20.00	12.04	10.22
5	27	76	23	0.	0.	17.86	15.32	0.23	0.00	4.40	3.69	2.8	7.83	17.0	5.9	20.00	11.09	9.44
6	1	76	10	22000.	4000.	120.09	33.25	2.07	0.00	62.46	59.44	15.0	8.40	17.0	4.5	0.00	0.00	0.00
6	1	76	11	7900.	3300.	34.57	23.12	0.57	0.00	6.06	5.50	3.6	8.39	18.5	5.1	0.00	0.00	0.00
6	1	76	12	0.	0.	******	35.58	2.00	0.00	50.00	47.77	15.0	7.72	17.0	4.9	20.00	16.87	0.00
6	1	76	13	0.	0.	******	38.07	2.11	0.00	50.53	48.20	15.0	7.72	17.0	4.9	20.00	16.09	0.00
6	1	76	14	0.	0.	109.07	14.09	1.96	0.00	49.67	47.67	15.0	7.80	17.0	5.6	20.00	15.75	0.00
6	1	76	15	0.	0.	******	37.60	2.37	0.00	46.33	44.40	14.0	7.70	17.0	4.8	20.00	16.87	0.00
6	1	76	16	0.	0.	******	37.60	1.89	0.00	43.67	42.87	13.0	7.65	17.0	4.9	20.00	15.87	0.00
6	1	76	17	0.	0.	103.62	36.98	1.94	0.00	45.20	43.40	13.0	7.75	17.0	5.6	20.00	14.86	0.00
6	1	76	18	5.	0.	******	37.06	2.37	0.00	44.73	42.80	13.0	7.88	17.0	4.8	19.27	12.63	0.00
6	1	76	19	2.	0.	******	37.60	2.37	0.00	43.33	41.27	12.0	7.90	17.0	4.9	19.27	11.84	0.00
6	1	76	20	1.	0.	101.29	40.41	2.17	0.00	41.27	39.27	13.0	7.92	17.0	5.9	19.27	11.28	0.00
6	1	76	21	0.	0.	******	23.43	0.06	0.00	5.36	5.36	4.4	7.64	19.0	5.3	20.00	9.83	6.65
6	1	76	22	0.	0.	******	24.83	0.20	0.00	6.04	5.40	4.2	7.71	18.0	5.3	20.00	9.72	6.60
6	1	76	23	0.	0.	31.61	29.19	0.09	0.00	5.68	4.92	4.4	7.79	18.0	6.7	20.00	9.50	6.70
6	3	76	10	79000.	13000.	109.93	32.34	0.53	0.00	53.43	49.90	15.0	9.20	18.5	10.5	0.00	0.00	0.00
6	3	76	11	3300.	800.	30.36	20.74	0.27	0.00	7.00	7.00	3.0	8.66	19.0	4.4	0.00	0.00	0.00
6	3	76	12	33.	5.	******	34.71	0.45	0.00	38.92	35.86	14.0	9.00	18.5	7.6	5.00	4.44	0.00
6	3	76	13	11.	5.	******	36.03	0.49	0.00	39.00	36.40	13.0	8.95	18.5	7.5	5.00	4.33	0.00
6	3	76	14	10.	2.	90.97	32.76	0.85	0.00	36.80	33.60	15.0	8.91	18.5	8.2	5.00	4.24	0.00
6	3	76	15	23.	5.	******	31.05	0.58	0.00	39.70	38.15	14.0	8.91	18.5	7.2	5.00	4.83	0.00
6	3	76	16	2.	2.	******	34.71	0.49	0.00	38.25	36.30	14.0	8.89	18.5	7.6	5.00	4.72	0.00
6	3	76	17	2.	2.	******	34.09	0.96	0.00	36.45	34.50	14.0	8.85	18.5	7.6	5.00	4.63	0.00
6	3	76	18	23.	17.	******	41.17	0.62	0.00	37.30	36.00	13.0	8.92	18.0	5.4	5.00	4.21	0.00
6	3	76	19	5.	0.	******	36.50	0.79	0.00	35.25	36.15	14.0	8.98	18.0	5.6	5.00	4.19	0.00
6	3	76	20	5.	0.	******	36.42	0.81	0.00	35.10	33.95	13.0	8.82	18.0	6.1	5.00	4.16	0.00
6	3	76	21	0.	0.	******	19.14	0.21	0.00	8.55	7.60	3.6	8.51	19.0	4.3	5.00	2.05	0.00
6	3	76	22	0.	0.	******	22.80	0.18	0.00	6.16	6.56	4.0	8.50	19.0	4.9	5.00	1.88	0.00
6	3	76	23	0.	0.	31.75	16.81	0.22	0.00	5.68	5.52	3.5	8.60	19.0	5.3	5.00	1.69	0.00
6	8	76	10	34000.	2000.	108.93	54.40	1.43	0.00	55.14	48.11	20.0	8.62	19.0	5.5	0.00	0.00	0.00
6	8	76	11	22000.	200.	25.75	23.55	0.45	0.00	6.98	5.92	4.4	8.42	21.5	3.9	0.00	0.00	0.00
6	8	76	12	11000.	140.	******	53.19	1.56	0.00	38.64	32.32	21.0	8.69	19.0	5.6	0.92	0.50	0.00
6	8	76	13	3300.	130.	******	44.21	1.63	0.00	29.93	25.[illegible]3	19.0	8.72	19.0	5.0	0.92	0.39	0.00
6	8	76	14	3000.	34.	83.79	48.63	1.53	0.00	32.07	26.67	18.0	8.72	19.0	5.3	0.92	0.28	0.00
6	8	76	15	110.	0.	******	57.88	1.55	0.00	33.93	30.67	21.0	8.55	19.0	4.2	4.59	4.89	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
6	8	76	16	0.	0.	******	47.32	1.46	0.00	29.40	23.73	15.0	8.54	19.0	5.9	4.59	4.75	0.00
6	8	76	17	0.	0.	66.66	47.12	1.56	0.00	29.47	23.33	20.0	8.59	19.0	6.0	4.59	4.64	0.00
6	8	76	18	700.	17.	******	45.61	1.50	0.00	34.67	29.87	18.0	8.68	19.0	5.6	2.75	1.84	0.00
6	8	76	19	49.	0.	******	41.58	1.53	0.00	25.80	22.20	17.0	8.65	19.0	4.7	2.75	1.76	0.00
6	8	76	20	35.	0.	71.08	42.43	1.74	0.00	26.40	22.80	16.0	8.68	19.0	6.7	2.75	1.68	0.00
6	8	76	21	540.	14.	******	23.15	0.38	0.00	5.80	4.76	5.5	8.42	21.0	4.2	2.75	1.48	0.00
6	8	76	22	130.	2.	******	27.26	0.42	0.00	6.16	4.92	5.4	8.43	21.0	4.6	2.75	1.40	0.00
6	8	76	23	5.	0.	31.44	25.71	0.46	0.00	6.68	5.44	5.4	8.43	21.0	5.8	2.75	1.37	0.00
6	8	76	10	310000.	4000.	118.59	55.28	1.46	0.00	59.07	51.40	20.0	8.50	20.5	5.1	0.00	0.00	0.00
6	8	76	12	940.	79.	******	45.92	1.44	0.00	34.33	29.87	21.0	8.63	20.5	5.0	1.83	1.23	0.00
6	8	76	13	240.	17.	******	52.19	1.26	0.00	31.20	27.40	15.0	8.69	20.5	4.6	1.83	1.12	0.00
6	8	76	14	240.	17.	96.63	52.96	1.59	0.00	29.75	25.60	19.0	8.74	20.5	4.9	1.83	1.03	0.00
6	8	76	15	17.	0.	******	48.32	1.75	0.00	33.33	29.73	20.0	8.45	20.5	4.3	5.50	5.75	0.00
6	8	76	16	0.	0.	******	51.03	1.85	0.00	29.07	25.40	21.0	8.42	20.5	4.9	5.50	5.47	0.00
6	8	76	17	0.	0.	101.20	44.68	1.67	0.00	31.40	26.93	22.0	8.48	20.5	5.1	5.50	5.25	0.00
6	8	76	18	110.	17.	******	50.41	1.34	0.00	39.53	34.60	25.0	8.58	20.5	4.6	3.67	2.35	0.00
6	8	76	19	33.	0.	******	58.61	1.38	0.00	36.93	32.13	24.0	8.55	20.5	4.7	3.67	2.15	0.00
6	8	76	20	17.	0.	109.94	52.73	1.42	0.00	36.07	30.33	23.0	9.56	20.5	5.2	3.67	2.01	0.00
6	10	76	10	350000.	2000.	74.66	43.80	2.04	0.00	32.40	26.90	15.0	8.08	20.0	3.8	0.00	0.00	0.00
6	10	76	11	35000.	200.	72.07	43.27	2.22	0.00	34.96	29.12	15.0	8.20	20.0	1.8	0.00	0.00	0.00
6	10	76	12	54000.	20.	******	45.05	2.14	0.00	16.50	14.00	15.0	8.43	19.0	4.8	0.92	0.47	0.00
6	10	76	13	3500.	50.	******	48.40	2.14	0.00	16.52	13.52	15.0	8.40	19.0	4.4	0.92	0.36	0.00
6	10	76	14	3000.	50.	72.75	46.38	2.23	0.00	16.00	13.12	15.0	8.44	19.0	5.2	0.92	0.30	0.00
6	10	76	15	79.	0.	******	43.68	2.03	0.00	18.64	15.64	15.0	8.25	19.0	5.0	4.59	4.48	0.00
6	10	76	16	0.	0.	******	44.60	2.12	0.00	15.08	12.16	14.0	8.24	19.0	4.5	4.59	4.40	0.00
6	10	76	17	0.	130.	67.28	48.40	2.08	0.00	16.16	12.28	14.0	8.22	19.0	5.1	4.59	4.31	0.00
6	10	76	18	3500.	17.	******	40.41	1.79	0.00	17.84	14.24	15.0	8.34	19.0	4.8	2.75	1.65	0.00
6	10	76	19	130.	0.	******	43.84	1.95	0.00	15.68	12.52	14.0	8.38	19.0	4.9	2.75	1.48	0.00
6	10	76	20	130.	0.	67.81	47.03	2.10	0.00	15.96	13.08	14.0	8.40	19.0	5.4	2.75	1.35	0.00
6	10	76	21	4900.	3.	******	24.05	1.05	0.00	5.36	4.28	3.7	8.24	20.0	4.4	1.83	0.91	0.00
6	10	76	22	750.	0.	******	24.05	0.97	0.00	5.28	4.60	4.0	8.23	20.0	4.4	1.83	0.77	0.00
6	10	76	23	330.	0.	33.33	25.42	0.99	0.00	5.68	4.52	4.2	8.23	20.0	4.8	1.83	0.69	0.00
6	10	76	10	130000.	2000.	90.18	68.95	2.06	0.00	42.32	36.16	15.0	8.23	20.0	3.7	0.00	0.00	0.00
6	10	76	12	750.	33.	******	51.39	2.08	0.00	19.76	17.92	15.0	8.33	20.0	4.2	1.83	1.13	0.00
6	10	76	13	130.	4.	******	52.21	2.22	0.00	19.00	16.04	16.0	8.32	20.0	4.7	1.83	1.02	0.00
6	10	76	14	130.	2.	73.52	72.22	2.03	0.00	17.40	15.12	15.0	8.33	20.0	4.5	1.83	0.96	0.00
6	10	76	15	11.	0.	******	66.89	2.02	0.00	20.56	17.76	16.0	8.15	20.0	3.8	5.50	5.82	0.00
6	10	76	16	2.	0.	******	66.97	2.03	0.00	16.52	14.16	15.0	8.13	20.0	4.4	5.50	5.66	0.00
6	10	76	17	2.	0.	93.30	68.19	2.17	0.00	15.56	13.56	15.0	8.16	20.0	4.5	5.50	5.49	0.00
6	10	76	18	110.	2.	******	72.00	1.76	0.00	19.28	11.28	16.0	8.28	20.0	4.0	3.67	3.53	0.00
6	10	76	19	13.	0.	******	74.81	2.02	0.00	18.56	15.60	15.0	8.25	20.0	4.0	3.67	3.49	0.00
6	10	76	20	13.	0.	94.44	72.75	2.04	0.00	18.40	15.28	15.0	8.30	20.0	4.6	3.67	3.44	0.00
6	15	76	10	54000.	3400.	52.52	24.96	2.91	0.00	18.94	17.08	8.6	8.06	14.0	6.2	0.00	0.00	0.00
6	15	76	11	35000.	3300.	18.96	20.91	0.81	0.00	3.62	2.84	4.0	8.15	15.0	6.3	0.00	0.00	0.00
6	15	76	12	7000.	490.	******	23.92	2.78	0.00	17.52	6.20	8.7	8.15	14.0	5.7	1.00	0.51	0.00
6	15	76	13	4600.	490.	******	22.21	2.72	0.00	17.28	15.56	8.9	8.19	14.0	5.6	1.00	0.45	0.00
6	15	76	14	3000.	7.	51.39	25.46	3.02	0.00	17.76	15.68	8.7	8.13	14.0	6.1	1.00	0.34	0.00
6	15	76	15	0.	0.	******	25.46	2.93	0.00	16.64	14.96	8.7	7.99	14.0	5.5	6.00	6.00	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
6	15	76	16	0.	0.	******	28.36	2.59	0.00	15.80	14.28	9.4	7.95	14.0	5.6	6.00	5.89	0.00
6	15	76	17	0.	0.	54.91	29.99	2.76	0.00	15.76	14.36	8.6	8.00	14.0	5.4	6.00	5.84	0.00
6	15	76	18	700.	110.	******	31.32	2.44	0.00	16.72	15.20	8.4	8.11	14.0	6.3	3.00	2.19	0.00
6	15	76	19	540.	0.	******	28.13	2.78	0.00	16.16	14.36	8.3	8.02	14.0	6.1	3.00	2.08	0.00
6	15	76	20	23.	0.	55.26	27.90	2.44	0.00	15.12	14.00	8.4	8.07	14.0	5.3	3.00	2.08	0.00
6	15	76	21	9200.	79.	******	22.17	0.63	0.00	3.56	2.44	3.3	8.09	15.0	5.6	1.00	0.73	0.00
6	15	76	22	1100.	5.	******	20.46	0.58	0.00	3.32	2.88	3.2	8.18	15.0	6.1	1.00	0.67	0.00
6	15	76	23	70.	0.	17.72	25.67	0.71	0.00	3.04	2.60	3.1	8.12	15.0	6.9	1.00	0.62	0.00
6	15	76	10	310000.	130000.	58.13	21.59	2.29	0.00	18.72	16.96	5.7	8.55	16.0	8.0	0.00	0.00	0.00
6	15	76	12	1100.	330.	******	29.10	2.05	0.00	15.12	13.88	8.7	8.30	14.0	6.9	2.00	1.63	0.00
6	15	76	13	170.	0.	******	24.46	2.18	0.00	15.20	13.64	9.2	8.30	15.0	7.6	2.00	1.54	0.00
6	15	76	14	44.	0.	57.97	25.77	2.35	0.00	14.96	13.76	7.9	8.25	14.5	7.8	2.00	1.40	0.00
6	15	76	15	0.	0.	******	25.31	1.96	0.00	14.40	12.84	8.3	7.98	15.0	6.2	10.00	9.89	0.00
6	15	76	16	0.	0.	******	25.62	2.13	0.00	15.04	13.64	8.6	7.93	15.0	7.6	10.00	9.78	0.00
6	15	76	17	0.	0.	57.82	21.08	2.18	0.00	14.32	13.12	8.6	8.09	15.0	7.5	10.00	9.66	0.00
6	15	76	18	7.	0.	******	21.59	2.35	0.00	15.28	13.76	9.4	8.43	15.5	7.7	4.00	2.92	0.00
6	15	76	19	0.	0.	******	30.42	2.22	0.00	16.40	14.56	9.2	8.25	15.0	7.8	4.00	2.81	0.00
6	15	76	20	0.	0.	51.86	21.98	2.00	0.00	15.56	14.36	8.6	8.13	15.0	7.6	4.00	2.75	0.00
6	17	76	10	79000.	33000.	62.51	23.76	2.57	0.00	25.24	22.40	8.9	7.77	16.0	5.3	0.00	0.00	0.00
6	17	76	12	79000.	13000.	******	23.53	2.64	0.00	22.76	20.32	11.0	8.05	15.5	5.5	1.00	0.00	0.00
6	17	76	13	49000.	11000.	******	21.94	2.42	0.00	22.28	19.88	11.0	8.05	15.0	5.4	1.00	0.00	0.00
6	17	76	14	79000.	3300.	58.90	25.43	2.40	0.00	21.96	19.44	10.0	7.10	15.0	5.9	1.00	0.00	0.00
6	17	76	15	17.	0.	******	24.29	2.38	0.00	21.20	19.44	11.0	7.95	15.0	5.4	6.00	3.68	0.00
6	17	76	16	13.	2.	******	26.87	2.54	0.00	20.68	18.72	11.0	7.88	15.0	5.7	6.00	3.61	0.00
6	17	76	17	13.	0.	57.84	27.70	2.30	0.00	20.72	18.48	11.0	7.80	15.0	6.0	6.00	3.53	0.00
6	17	76	18	330.	14.	******	27.32	2.56	0.00	21.04	18.72	11.0	7.95	15.0	5.4	4.00	2.74	0.00
6	17	76	19	17.	0.	******	25.88	2.34	0.00	17.84	18.84	10.0	7.91	15.0	5.2	4.00	2.56	0.00
6	17	76	20	17.	0.	59.81	27.32	2.48	0.00	24.16	18.80	10.0	8.02	15.0	5.7	4.00	2.49	0.00
6	17	76	10	460000.	110000.	68.54	16.85	1.75	0.00	27.52	24.76	12.0	8.28	16.0	7.6	0.00	0.00	0.00
6	17	76	12	3500.	280.	******	23.91	1.99	0.00	22.32	20.12	9.1	8.15	16.0	6.0	2.00	1.58	0.00
6	17	76	13	920.	0.	******	16.70	1.99	0.00	21.88	19.72	11.0	8.12	16.0	5.9	2.00	1.47	0.00
6	17	76	14	220.	2.	61.86	21.48	2.28	0.00	22.08	20.40	11.0	8.04	16.0	5.9	2.00	1.37	0.00
6	17	76	15	340.	0.	******	33.09	2.08	0.00	20.60	19.24	12.0	8.15	16.0	6.1	5.00	2.99	0.00
6	17	75	16	7.	0.	******	25.96	1.94	0.00	20.12	18.92	11.0	8.05	16.0	7.2	5.00	2.86	0.00
6	17	76	17	7.	0.	63.15	24.06	1.94	0.00	20.76	19.24	10.0	8.09	16.0	6.5	5.00	2.86	0.00
6	17	76	18	2.	0.	******	23.53	1.55	0.00	20.28	19.12	9.0	7.98	16.0	6.5	8.00	6.37	0.00
6	17	76	19	2.	0.	******	24.36	1.73	0.00	20.52	18.12	9.4	8.05	15.0	7.0	8.00	6.32	0.00
6	17	76	20	2.	0.	32.69	25.58	1.79	0.00	19.16	17.28	10.0	7.95	16.0	7.0	8.00	6.17	0.00
6	22	76	10	47000.	33000.	84.91	26.15	0.60	0.00	38.43	34.43	15.0	8.78	19.0	9.3	0.00	0.00	0.00
6	22	76	11	54000.	490.	22.65	16.89	0.17	0.00	5.54	5.44	3.1	9.13	20.5	5.5	0.00	0.00	0.00
6	22	76	12	70000.	33000.	******	21.60	0.76	0.00	29.66	27.11	12.0	8.78	19.5	4.5	1.00	0.38	0.00
6	22	76	13	49000.	17000.	******	22.10	0.78	0.00	28.75	27.70	12.0	9.72	17.0	3.1	1.00	0.33	0.00
6	22	76	14	23000.	13000.	68.97	25.02	0.63	0.00	23.48	23.48	12.0	8.75	19.0	5.1	1.00	0.25	0.00
6	22	76	15	5400.	790.	******	24.35	0.65	0.00	23.20	22.20	12.0	8.55	18.0	6.7	3.00	1.50	0.00
6	22	76	16	3500.	260.	******	27.11	0.48	0.00	27.55	25.40	13.0	9.65	17.0	4.5	3.00	1.30	0.00
6	22	76	17	790.	23.	68.22	26.36	0.74	0.00	28.65	26.70	12.0	8.67	19.0	7.4	3.00	1.18	0.00
6	22	76	18	130.	13.	******	26.36	0.75	0.00	27.10	25.25	12.0	8.58	16.0	4.1	5.00	3.33	0.00
6	22	76	19	13.	5.	******	25.77	0.61	0.00	27.25	27.25	13.0	8.51	17.0	6.0	5.00	3.10	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
6	22	76	20	11.	1.	68.72	29.27	0.63	0.00	21.00	21.00	11.0	8.60	19.0	7.4	5.00	2.95	0.00
6	22	76	21	7900.	490.	******	16.76	0.13	0.00	5.60	5.36	3.1	8.25	20.0	5.9	0.50	0.25	0.00
6	22	76	22	24000.	790.	******	15.43	0.15	0.00	6.08	5.84	3.2	8.25	20.0	6.1	0.50	0.20	0.00
6	22	76	23	24000.	330.	25.69	15.85	0.15	0.00	5.84	5.84	3.4	8.25	20.0	6.4	0.50	0.18	0.00
6	22	76	10	310000.	130000.	125.20	34.53	0.36	0.00	50.80	46.65	16.0	8.91	20.0	6.5	0.00	0.00	0.00
6	22	76	12	14000.	4600.	******	36.36	0.78	0.00	43.07	39.87	15.0	8.62	20.0	5.6	2.00	1.15	0.00
6	22	76	13	3500.	490.	******	42.37	0.57	0.00	38.33	36.60	17.0	8.67	20.0	4.6	2.00	0.95	0.00
6	22	76	14	3000.	79.	102.92	37.78	0.65	0.00	36.40	34.90	17.0	8.68	20.0	5.5	2.00	0.85	0.00
6	22	76	15	3500.	790.	******	47.37	0.59	0.00	39.93	37.73	15.0	8.67	20.0	5.1	4.00	2.95	0.00
6	22	76	16	490.	33.	******	44.20	0.53	0.00	34.40	32.93	13.0	8.65	20.0	5.1	4.00	1.80	0.00
6	22	76	17	70.	0.	86.99	35.61	0.60	0.00	31.27	29.33	14.0	8.67	20.0	5.2	4.00	1.65	0.00
6	22	76	18	130.	11.	******	37.70	0.55	0.00	32.13	29.80	15.0	8.58	20.0	4.8	6.00	3.83	0.00
6	22	76	19	11.	2.	******	38.53	0.50	0.00	29.73	29.26	13.0	8.57	20.0	4.5	6.00	3.63	0.00
6	22	76	20	11.	2.	78.57	40.28	0.53	0.00	25.20	24.87	14.0	8.57	20.0	4.9	6.00	3.40	0.00
6	24	76	10	17000.	500.	97.70	31.62	1.74	0.00	26.72	25.18	13.0	8.71	16.0	6.5	0.00	0.00	0.00
6	24	76	11	160000.	790.	22.10	19.12	0.24	0.00	13.70	6.50	10.5	8.62	17.0	3.9	0.00	0.00	0.00
6	24	76	12	22000.	170.	******	34.26	0.31	0.00	31.60	28.67	14.0	8.75	16.0	5.3	1.00	0.32	0.00
6	24	76	13	13000.	460.	******	35.84	0.29	0.00	30.53	27.73	15.0	8.67	16.0	5.6	1.00	0.22	0.00
6	24	76	14	16000.	230.	86.99	34.43	0.32	0.00	31.93	29.07	15.0	8.75	16.0	6.0	1.00	0.20	0.00
6	24	76	15	5400.	46.	******	36.91	0.33	0.00	31.07	29.20	16.0	8.65	16.5	5.2	3.00	1.35	0.00
6	24	76	16	2400.	63.	******	40.22	0.34	0.00	29.07	26.53	15.0	8.68	16.5	6.0	3.00	1.28	0.00
6	24	76	17	9200.	2.	91.87	41.22	0.33	0.00	30.67	27.67	15.0	8.70	16.0	5.9	3.00	1.23	0.00
6	24	76	18	1100.	8.	******	42.21	0.33	0.00	32.13	27.60	15.0	8.62	16.0	3.2	5.00	2.76	0.00
6	24	76	19	490.	13.	******	44.36	0.43	0.00	29.40	25.53	15.0	8.63	16.5	5.0	5.00	2.68	0.00
6	24	76	20	490.	13.	83.26	38.57	0.40	0.00	27.73	26.93	15.0	8.64	16.5	5.5	5.00	2.59	0.00
6	24	76	21	0.	0.	******	20.36	0.28	0.00	13.60	7.44	11.0	8.18	17.0	3.9	2.00	1.35	0.00
6	24	76	22	240.	2.	******	20.03	0.24	0.00	12.76	7.64	12.0	8.23	16.5	4.2	2.00	1.30	0.00
6	24	76	23	8.	0.	27.81	16.55	0.23	0.00	13.04	6.04	11.0	8.23	16.0	4.4	2.00	1.26	0.00
6	24	76	10	430000.	9000.	130.68	34.76	0.39	0.00	49.07	44.80	17.0	8.10	17.0	6.3	0.00	1.26	0.00
6	24	76	12	700.	230.	******	34.51	0.36	0.00	36.40	33.87	16.0	8.51	1.0	6.8	2.00	1.28	0.00
6	24	76	13	70.	11.	******	34.43	0.42	0.00	31.73	29.00	15.0	8.31	17.0	7.3	2.00	1.11	0.00
6	24	76	14	57.	5.	87.56	48.91	*****	0.00	33.20	28.30	15.0	8.35	17.0	6.5	2.00	1.03	0.00
6	24	76	15	230.	23.	******	34.60	0.34	0.00	31.60	31.33	16.0	8.27	17.0	6.0	4.00	2.17	0.00
6	24	76	16	130.	0.	******	35.67	0.34	0.00	29.60	26.80	15.0	8.22	17.0	6.3	4.00	2.04	0.00
6	24	76	17	90.	0.	84.75	36.91	0.34	0.00	29.73	27.80	16.0	8.42	17.0	6.8	4.00	2.00	0.00
6	24	76	18	8.	0.	******	36.91	0.29	0.00	29.80	25.20	15.0	7.98	17.0	7.0	9.92	3.72	0.00
6	24	76	19	8.	0.	******	108.92	0.26	0.00	29.53	27.73	15.0	8.12	17.0	6.8	9.92	3.45	0.00
6	24	76	20	8.	0.	83.92	41.72	0.25	0.00	28.87	6.13	15.0	7.82	17.0	6.8	9.92	3.25	0.00
7	1	76	10	70000.	14000.	57.18	31.39	4.26	0.00	15.08	12.04	10.0	8.10	20.0	3.9	0.00	0.00	0.00
7	1	76	11	49000.	2800.	37.28	25.23	3.56	0.00	6.20	4.94	4.1	7.97	23.0	3.7	0.00	0.00	0.00
7	1	76	12	22000.	1200.	******	36.83	3.58	0.00	15.44	12.64	11.0	8.03	20.0	4.8	1.00	0.30	0.00
7	1	76	13	33000.	1300.	******	38.44	4.20	0.00	14.80	12.20	11.0	8.00	20.0	5.0	1.00	0.25	0.00
7	1	76	14	33000.	4300.	62.30	30.11	4.20	0.00	14.72	11.92	10.0	8.05	20.0	5.4	1.00	0.22	0.00
7	1	76	15	1700.	170.	******	34.83	4.20	0.00	14.72	11.72	10.0	7.97	20.0	4.6	3.00	1.43	0.00
7	1	76	16	130.	4.	******	40.92	3.45	0.00	12.88	12.08	10.0	7.98	20.0	4.7	3.00	1.33	0.00
7	1	76	17	50.	0.	62.94	38.92	3.58	0.00	13.52	11.28	11.0	8.05	20.0	5.5	3.00	1.26	0.00
7	1	76	18	49.	17.	******	38.92	3.73	0.00	12.52	10.52	11.0	7.90	20.0	4.8	5.00	2.88	0.00
7	1	76	19	33.	5.	******	36.75	4.05	0.00	13.20	10.52	11.0	7.88	19.5	4.7	5.00	2.78	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
7	1	76	20	47.	2.	67.58	44.92	3.43	0.00	14.56	11.76	11.0	7.93	20.0	5.1	5.00	2.59	0.00
7	1	76	21	24000.	5400.	******	25.62	3.06	0.00	6.00	5.12	5.1	7.99	22.5	4.5	1.00	0.57	0.00
7	1	76	22	5400.	280.	******	27.95	3.12	0.00	60.00	50.00	52.0	8.08	22.5	4.6	1.00	0.47	0.00
7	1	76	23	3500.	26.	35.79	26.10	2.93	0.00	6.32	5.16	5.8	8.02	22.5	5.1	1.00	0.44	0.00
7	1	76	10	310000.	230000.	53.40	32.03	3.23	0.00	13.84	11.96	8.7	7.95	20.5	3.6	0.00	0.00	0.00
7	1	76	12	2300.	330.	******	29.46	3.62	0.00	13.00	9.88	8.4	8.07	20.5	4.5	2.00	1.26	0.00
7	1	76	13	23.	5.	******	33.39	3.43	0.00	15.36	9.36	8.5	8.01	20.5	4.2	2.00	1.16	0.00
7	1	76	14	23.	0.	55.24	33.79	3.54	0.00	11.80	10.32	8.9	8.00	20.5	4.4	2.00	1.08	0.00
7	1	76	15	230.	7.	******	37.15	3.69	0.00	10.40	19.16	8.6	7.95	20.5	4.5	4.00	1.63	0.00
7	1	76	16	11.	0.	******	36.83	4.85	0.00	10.80	9.24	8.6	7.99	20.5	4.8	4.00	1.58	0.00
7	1	76	17	0.	0.	54.20	34.35	3.60	0.00	11.40	9.84	8.7	8.00	20.5	4.9	4.00	1.50	0.00
7	1	76	18	0.	0.	******	32.27	3.25	0.00	10.76	9.00	8.7	7.80	20.5	4.3	20.00	8.28	0.00
7	1	76	19	0.	0.	******	38.19	3.30	0.00	10.56	9.16	9.0	7.77	20.5	4.7	20.00	7.98	0.00
7	1	76	20	0.	0.	48.04	37.87	3.75	0.00	10.92	9.24	9.0	7.85	20.5	4.8	20.00	7.68	0.00
7	1	76	21	3500.	17.	******	26.98	2.72	0.00	5.80	5.08	4.7	7.97	22.5	5.2	2.00	1.40	0.00
7	1	76	22	0.	0.	******	21.70	2.91	0.00	4.92	4.16	4.9	7.91	22.5	5.4	2.00	1.26	0.00
7	1	76	23	0.	0.	29.62	23.94	2.97	0.00	6.16	5.20	5.0	7.94	22.5	5.8	2.00	1.16	0.00
7	6	76	10	33000.	500.	109.35	43.67	2.53	0.00	64.53	48.93	28.0	8.90	21.0	3.3	0.00	0.00	0.00
7	6	76	11	24000.	1300.	37.32	30.88	2.45	0.00	5.84	4.84	4.6	7.86	21.5	3.2	0.00	0.00	0.00
7	6	76	12	79.	0.	******	53.47	1.66	0.00	30.96	25.16	18.0	7.92	21.0	3.7	5.00	2.24	0.00
7	6	76	13	5.	0.	******	51.69	1.51	0.00	31.87	26.40	17.0	7.95	21.0	3.2	5.00	2.11	0.00
7	6	76	14	0.	0.	84.59	59.52	1.58	0.00	60.07	20.07	19.0	7.95	21.0	4.5	5.00	2.01	0.00
7	6	76	15	23000.	490.	******	47.20	1.79	0.00	40.53	32.53	21.0	8.03	21.0	3.2	1.00	0.25	0.00
7	6	76	16	33000.	490.	******	48.67	2.09	0.00	36.27	28.47	21.0	8.04	21.0	3.0	1.00	0.17	0.00
7	6	76	17	33000.	490.	84.95	41.70	2.83	0.00	33.27	26.73	20.0	8.12	21.0	4.1	1.00	0.10	0.00
7	6	76	18	330.	130.	******	54.09	2.06	0.00	40.73	33.73	22.0	7.95	21.0	3.2	3.00	0.92	0.00
7	6	76	19	240.	4.	******	41.67	2.06	0.00	38.07	28.87	23.0	7.93	21.0	4.0	3.00	0.67	0.00
7	6	76	20	240.	2.	84.01	43.24	2.20	0.00	33.87	25.40	22.0	7.99	21.0	4.5	3.00	0.55	0.00
7	6	76	21	130.	11.	******	28.36	1.15	0.00	5.60	2.76	5.2	7.89	21.0	4.1	3.00	1.52	0.00
7	6	76	22	14.	0.	******	32.55	3.54	0.00	5.76	4.68	5.3	7.96	21.0	4.4	3.00	1.47	0.00
7	6	76	23	0.	0.	37.04	27.98	1.75	0.00	5.76	4.92	5.4	7.96	21.0	4.6	3.00	1.42	0.00
7	6	76	10	79000.	2000.	95.94	44.10	0.74	0.00	25.07	22.00	13.0	8.43	23.0	6.4	0.00	0.00	0.00
7	6	76	12	5.	0.	******	46.50	0.75	0.00	16.88	14.12	12.0	8.00	23.0	4.5	10.00	5.12	0.00
7	6	76	13	0.	0.	******	49.60	0.95	0.00	14.92	12.76	12.0	8.02	23.0	4.4	10.00	5.92	0.00
7	6	76	14	0.	0.	68.66	43.79	0.61	0.00	16.96	14.64	11.0	8.00	23.0	5.8	10.00	5.72	0.00
7	6	76	15	80.	20.	******	45.03	0.73	0.00	17.16	14.44	12.0	8.25	23.0	3.9	2.00	1.02	0.00
7	6	76	16	20.	0.	******	43.24	0.78	0.00	15.48	13.60	11.0	8.26	23.0	3.8	2.00	0.85	0.00
7	6	76	17	0.	0.	66.65	42.47	0.75	0.00	16.08	13.72	11.0	8.23	23.0	5.6	2.00	0.67	0.00
7	6	76	18	49.	2.	******	45.72	0.73	0.00	17.04	14.44	12.0	8.18	23.0	4.4	4.00	1.27	0.00
7	6	76	19	7.	0.	******	44.64	0.79	0.00	16.32	13.40	12.0	8.20	23.0	3.9	4.00	1.12	0.00
7	6	76	20	0.	0.	72.54	48.05	0.87	0.00	15.32	13.09	12.0	8.23	23.0	5.1	4.00	0.95	0.00
7	6	76	21	49.	5.	******	34.56	1.05	0.00	5.72	7.21	5.0	7.88	23.0	3.7	4.00	1.87	0.00
7	6	76	22	0.	0.	******	33.94	1.05	0.00	5.20	4.80	5.2	7.80	22.0	3.5	4.00	1.82	0.00
7	6	76	23	0.	0.	44.79	32.01	0.89	0.00	9.56	9.48	5.4	7.92	22.0	4.2	4.00	1.72	0.00
7	8	76	10	7900.	500.	60.96	25.35	2.12	0.00	29.67	25.76	11.0	8.58	22.0	7.3	0.00	0.00	0.00
7	8	76	11	33000.	210.	37.52	21.82	1.94	0.00	10.78	9.49	4.5	8.12	24.0	2.9	0.00	0.00	0.00
7	8	76	12	26.	2.	******	34.22	2.43	0.00	21.00	17.32	11.0	8.37	21.5	6.1	5.00	2.44	0.00
7	8	76	13	0.	0.	******	31.49	1.92	0.00	19.92	15.60	12.0	8.37	21.5	6.1	5.00	2.39	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
7	8	76	14	0.	0.	64.57	37.25	1.57	0.00	20.40	17.64	12.0	8.38	21.5	6.2	5.00	2.34	0.00
7	8	76	15	7900.	790.	******	32.25	3.44	0.00	21.44	18.36	13.0	8.52	21.5	6.2	1.00	0.35	0.00
7	8	76	16	7900.	490.	******	37.70	2.08	0.00	19.84	18.96	12.0	8.52	21.5	5.7	1.00	0.32	0.00
7	8	76	17	4900.	170.	60.02	32.70	2.10	0.00	19.20	16.80	11.0	8.48	21.5	6.0	1.00	0.27	0.00
7	8	76	18	1400.	35.	******	34.65	2.08	0.00	19.44	16.76	11.0	8.50	22.0	5.3	3.00	0.90	0.00
7	8	76	19	170.	4.	******	34.22	1.85	0.00	18.16	15.88	10.0	8.51	22.0	4.7	3.00	0.80	0.00
7	8	76	20	170.	4.	60.02	35.36	1.99	0.00	18.40	16.08	10.0	8.10	22.0	6.1	3.00	0.75	0.00
7	8	76	21	2400.	110.	******	22.15	1.78	0.00	9.36	9.32	5.8	8.07	23.5	3.5	1.00	0.65	0.00
7	8	76	22	490.	2.	******	23.52	1.68	0.00	9.48	9.00	5.5	8.13	23.5	4.0	1.00	0.50	0.00
7	8	76	23	49.	0.	34.98	23.82	1.61	0.00	10.00	3.76	5.7	8.09	23.5	2.9	1.00	0.40	0.00
7	8	76	10	79000.	2000.	78.22	40.17	1.87	0.00	32.20	27.88	13.0	8.52	23.0	7.5	0.00	0.00	0.00
7	8	76	12	5.	0.	******	36.49	1.29	0.00	20.04	14.12	12.0	4.90	23.0	6.0	20.00	9.20	0.00
7	8	76	13	0.	0.	******	38.85	1.01	0.00	19.24	16.88	13.0	7.90	23.0	5.9	20.00	8.76	0.00
7	8	76	14	0.	0.	62.67	35.74	1.15	0.00	19.20	16.40	12.0	7.91	23.0	6.5	20.00	8.56	0.00
7	8	76	15	230.	20.	******	33.76	1.66	0.00	19.32	17.04	12.0	8.45	23.0	6.5	2.00	0.77	0.00
7	8	76	16	80.	20.	******	35.74	1.78	0.00	19.48	17.12	11.0	8.44	23.0	6.6	2.00	0.72	0.00
7	8	76	17	80.	20.	63.05	41.81	1.94	0.00	18.32	15.80	12.0	8.38	23.0	6.5	2.00	0.67	0.00
7	8	76	18	79.	7.	******	35.66	1.92	0.00	18.68	15.76	12.0	8.39	23.0	5.9	4.00	1.27	0.00
7	8	76	19	2.	0.	******	36.87	1.61	0.00	19.20	16.60	12.0	8.40	23.0	6.6	4.00	1.12	0.00
7	8	76	20	0.	0.	64.57	38.16	1.85	0.00	18.84	16.20	11.0	8.40	23.0	6.3	4.00	1.04	0.00
7	8	76	21	0.	0.	******	28.83	*****	0.00	10.24	9.44	6.2	7.73	23.5	3.4	20.00	3.31	0.00
7	8	76	22	0.	0.	******	26.78	*****	0.00	9.84	9.48	6.4	7.62	23.5	3.7	20.00	3.18	0.00
7	8	76	23	0.	0.	41.81	23.60	*****	0.00	9.76	9.48	6.3	7.70	23.5	4.0	20.00	2.99	0.00
7	13	76	10	49000.	17000.	54.33	34.16	3.18	0.00	11.28	8.70	13.0	8.20	22.2	4.9	0.00	0.00	0.00
7	13	76	11	17000.	3300.	39.18	30.11	2.72	0.00	6.38	5.00	5.7	7.91	23.5	2.2	0.00	0.00	0.00
7	13	76	12	1300.	27.	******	38.49	2.90	0.00	10.00	7.88	12.0	8.04	22.0	4.8	5.00	1.92	0.00
7	13	76	13	17.	2.	******	33.14	3.01	0.00	10.24	7.72	13.0	8.18	21.9	4.4	5.00	1.85	0.00
7	13	76	14	4.	0.	54.54	36.22	2.90	0.00	10.36	7.56	12.0	8.19	21.9	3.9	5.00	1.77	0.00
7	13	76	15	17000.	3300.	******	36.30	3.16	0.00	10.60	8.40	12.0	8.28	22.0	3.9	1.00	0.26	0.00
7	13	76	16	4900.	1100.	******	39.22	3.28	0.00	10.24	8.00	12.0	8.30	20.0	3.7	1.00	0.24	0.00
7	13	76	17	4900.	940.	56.62	38.25	3.31	0.00	10.48	8.28	12.0	8.28	21.6	4.8	1.00	0.21	0.00
7	13	76	18	750.	490.	******	37.93	2.95	0.00	9.16	7.40	13.0	8.21	21.8	4.9	3.00	1.13	0.00
7	13	76	19	140.	13.	******	41.57	2.97	0.00	10.00	7.60	13.0	8.22	21.8	5.2	3.00	0.98	0.00
7	13	76	20	33.	4.	41.98	35.49	3.07	0.00	10.28	7.76	13.0	8.27	21.8	4.2	3.00	0.88	0.00
7	13	76	21	750.	230.	******	31.85	2.80	0.00	5.76	4.92	6.8	8.11	23.2	3.6	2.00	1.13	0.00
7	13	76	22	4.	2.	******	28.77	2.52	0.00	6.00	4.80	6.7	8.10	23.1	3.9	2.00	1.08	0.00
7	13	76	23	2.	0.	39.55	31.77	2.54	0.00	5.92	4.28	6.6	8.12	23.1	3.8	2.00	1.08	0.00
7	13	76	10	23000.	3300.	54.13	36.31	2.86	0.00	11.80	9.12	12.0	8.22	23.0	4.8	0.00	0.00	0.00
7	13	76	12	0.	0.	******	33.63	2.90	0.00	9.88	8.44	12.0	8.09	24.0	6.1	10.00	5.19	0.00
7	13	76	13	0.	0.	******	33.63	2.69	0.00	9.76	7.44	12.0	8.08	24.0	6.0	10.00	5.04	0.00
7	13	76	14	0.	0.	55.75	37.12	2.59	0.00	9.64	7.96	13.0	8.07	24.0	6.3	10.00	4.94	0.00
7	13	76	15	33030.	130.	******	32.25	2.73	0.00	10.10	8.04	13.0	8.21	23.0	5.8	2.00	1.03	0.00
7	13	76	16	4.	20.	******	34.93	3.07	0.00	9.44	7.52	11.0	8.19	24.0	5.7	2.00	0.96	0.00
7	13	76	17	0.	0.	50.08	37.93	2.95	0.00	9.48	7.72	13.0	8.25	24.0	6.1	2.00	0.91	0.00
7	13	76	18	1300.	490.	******	33.47	2.67	0.00	9.44	7.16	11.0	8.19	23.0	6.0	4.00	1.50	0.00
7	13	76	19	23.	2.	******	37.12	3.07	0.00	8.80	6.72	12.0	8.20	23.0	5.8	4.00	1.30	0.00
7	13	76	20	0.	0.	49.27	34.52	3.01	0.00	9.32	7.76	12.0	8.19	23.0	5.3	4.00	1.20	0.00
7	13	76	21	220.	240.	******	28.20	2.59	0.00	6.00	5.04	6.6	8.00	23.0	3.5	3.00	1.40	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
7	13	76	22	5.	5.	******	26.58	2.52	0.00	5.76	4.36	6.5	8.01	23.0	3.2	3.00	1.30	0.00
7	13	76	23	0.	0.	40.03	29.82	2.54	0.00	6.16	4.28	6.8	8.09	23.0	3.0	3.00	1.20	0.00
7	15	76	10	460.	800.	84.76	43.90	3.47	0.00	26.38	22.66	11.0	8.00	21.0	4.2	0.00	0.00	0.00
7	15	76	11	11000.	330.	28.44	25.02	1.98	0.00	4.22	3.74	3.8	7.85	23.5	3.8	0.00	0.00	0.00
7	15	76	12	94.	23.	******	37.12	3.51	0.00	12.84	11.32	8.4	7.91	20.5	5.2	5.00	2.11	0.00
7	15	76	13	49.	11.	******	38.56	3.05	0.00	10.04	8.68	8.4	7.98	20.5	5.2	5.00	1.99	0.00
7	15	76	14	2.	0.	61.10	41.74	2.10	0.00	8.76	7.52	9.5	7.98	20.5	6.3	5.00	1.89	0.00
7	15	76	15	4600.	330.	******	36.25	3.47	0.00	12.32	10.36	5.3	8.01	20.5	6.1	1.00	0.41	0.00
7	15	76	16	4600.	330.	******	36.17	3.43	0.00	10.08	7.96	8.7	8.04	20.5	4.6	1.00	0.38	0.00
7	15	76	17	4600.	490.	60.23	46.52	3.47	0.00	10.12	8.98	8.7	8.00	20.5	4.5	1.00	0.33	0.00
7	15	76	18	2400.	490.	******	47.24	3.08	0.00	12.88	10.68	9.6	8.05	21.0	5.4	3.00	0.79	0.00
7	15	76	19	790.	79.	******	49.47	3.28	0.00	11.48	10.08	9.3	8.02	21.0	5.8	3.00	0.67	0.00
7	15	76	20	490.	79.	59.27	41.03	2.99	0.00	10.84	9.36	9.7	8.06	21.0	5.8	3.00	0.92	0.00
7	15	76	21	2200.	130.	******	21.59	2.18	0.00	4.76	4.00	4.6	7.92	23.0	4.6	1.00	0.55	0.00
7	15	76	22	1700.	70.	******	23.74	2.22	0.00	4.16	3.84	4.5	7.98	23.0	5.1	1.00	0.50	0.00
7	15	76	23	220.	7.	30.35	18.64	2.04	0.00	4.16	3.32	4.4	7.99	23.0	6.1	1.00	0.50	0.00
7	15	76	10	13000.	1700.	68.03	37.76	3.35	0.00	14.64	12.52	9.0	8.05	22.0	4.4	0.00	0.00	0.00
7	15	76	12	5.	0.	******	38.56	3.70	0.00	7.64	6.72	8.7	7.88	22.0	6.3	15.00	8.76	0.00
7	15	76	13	0.	0.	******	36.01	3.05	0.00	6.76	5.92	8.3	7.80	22.0	6.5	15.00	8.66	0.00
7	15	76	14	0.	0.	52.10	36.81	3.03	0.00	6.60	5.96	8.2	7.78	22.0	6.8	15.00	8.47	0.00
7	15	76	15	460.	230.	******	35.69	3.17	0.00	7.88	6.16	8.0	8.02	22.0	6.5	2.00	0.89	0.00
7	15	76	16	130.	20.	******	35.05	3.39	0.00	7.32	6.28	8.1	8.06	22.0	6.2	2.00	0.79	0.00
7	15	76	17	20.	2.	49.47	35.21	3.28	0.00	6.76	5.60	8.0	8.03	22.0	6.8	2.00	0.74	0.00
7	15	76	18	220.	33.	******	36.96	3.03	0.00	7.08	6.04	8.1	8.02	22.0	6.4	4.00	1.22	0.00
7	15	76	19	5.	2.	******	35.37	3.14	0.00	7.24	6.28	8.2	8.04	22.0	5.9	4.00	1.05	0.00
7	15	76	20	4.	0.	47.32	37.76	3.14	0.00	7.20	5.92	8.2	8.03	22.0	6.4	4.00	0.98	0.00
7	15	76	21	0.	0.	******	24.86	2.08	0.00	5.00	4.40	4.6	7.70	23.0	5.1	15.00	9.90	0.00
7	15	76	22	0.	0.	******	27.41	1.29	0.00	3.28	4.44	4.5	7.75	23.0	5.3	15.00	9.52	0.00
7	15	76	23	0.	0.	29.16	23.50	1.60	0.00	5.04	4.48	4.3	7.72	23.0	5.4	15.00	9.23	0.00
7	20	76	10	2300.	200.	76.13	48.50	3.43	0.00	33.16	28.14	17.0	8.00	22.0	4.4	0.00	0.00	0.00
7	20	76	11	7900.	460.	28.72	21.74	2.34	0.00	4.82	4.28	4.3	8.05	23.0	5.7	0.00	0.00	0.00
7	20	76	12	79.	2.	******	53.99	3.28	0.00	23.28	19.56	20.0	7.92	21.5	4.4	5.00	1.42	0.00
7	20	76	13	23.	0.	******	39.79	3.10	0.00	20.44	16.54	18.0	7.92	21.5	4.8	5.00	1.35	0.00
7	20	76	14	2.	0.	76.67	42.14	3.24	0.00	19.28	17.24	18.0	7.84	21.5	4.1	5.00	1.30	0.00
7	20	76	15	2300.	80.	******	38.61	2.95	0.00	19.60	16.28	18.0	7.98	21.8	4.3	1.00	0.29	0.00
7	20	76	16	2200.	20.	******	34.29	3.15	0.00	21.16	18.00	17.0	8.07	21.5	4.3	1.00	0.22	0.00
7	20	76	17	1100.	70.	71.65	33.75	3.24	0.00	18.76	16.20	16.0	8.08	21.4	4.5	1.00	0.17	0.00
7	20	76	15	790.	17.	******	31.94	3.28	0.00	19.32	15.68	16.0	8.09	21.3	4.5	3.00	0.74	0.00
7	20	76	19	130.	2.	******	31.16	3.24	0.00	18.04	11.52	15.0	8.03	21.6	4.5	3.00	0.69	0.00
7	20	76	20	79.	0.	57.05	30.76	2.32	0.00	15.92	14.56	15.0	7.98	21.5	5.5	3.00	0.59	0.00
7	20	76	21	2.	0.	******	35.94	2.14	0.00	5.00	4.04	4.6	7.98	22.5	4.9	4.00	1.81	0.00
7	20	76	22	0.	0.	******	41.91	2.84	0.00	4.76	4.32	4.5	7.98	22.4	4.4	4.00	1.74	0.00
7	20	76	23	0.	0.	42.85	38.38	2.05	0.00	4.88	4.28	4.7	7.98	22.2	4.6	4.00	1.72	0.00
7	20	76	10	2300.	130.	48.89	33.51	3.43	0.00	37.72	31.00	20.0	7.95	23.0	5.0	0.00	0.00	0.00
7	20	76	12	0.	0.	******	40.73	3.23	0.00	14.88	13.00	16.0	7.38	23.0	6.4	20.00	11.52	0.00
7	20	76	13	0.	0.	******	35.08	3.08	0.00	13.60	11.20	17.0	7.51	23.0	6.6	20.00	11.27	0.00
7	20	76	14	0.	0.	64.43	39.40	3.02	0.00	12.64	11.40	17.0	7.52	23.0	6.8	20.00	11.20	0.00
7	20	76	15	60.	20.	******	34.84	2.99	0.00	21.56	17.80	16.0	7.75	23.0	6.1	2.00	0.76	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
7	20	76	16	20.	2.	******	34.14	2.95	0.00	18.44	15.08	16.0	7.89	23.0	5.9	2.00	0.64	0.00
7	20	76	17	2.	0.	64.90	36.10	3.08	0.00	17.96	14.56	18.0	7.92	23.0	6.0	2.00	0.59	0.00
7	20	76	18	490.	7.	******	33.20	3.04	0.00	19.08	15.36	17.0	7.90	23.0	6.3	4.00	1.13	0.00
7	20	76	19	6.	0.	******	36.49	3.11	0.00	18.60	14.84	17.0	7.92	23.0	6.3	4.00	0.93	0.00
7	20	76	20	2.	0.	58.23	37.43	3.10	0.00	18.56	15.04	16.0	7.95	23.0	6.2	4.00	0.78	0.00
7	20	76	21	0.	0.	******	18.60	2.03	0.00	4.72	4.16	4.7	7.85	23.0	6.8	5.00	2.60	0.00
7	20	76	22	0.	0.	******	20.25	1.88	0.00	4.16	3.68	5.0	7.89	23.0	6.8	5.00	2.55	0.00
7	20	76	23	0.	0.	25.35	21.97	1.84	0.00	4.96	4.04	4.7	7.85	23.0	6.9	5.00	2.50	0.00
7	22	76	10	7000.	230.	68.77	38.07	3.27	0.00	24.48	19.66	16.0	7.95	22.0	4.2	0.00	0.00	0.00
7	22	76	11	4900.	330.	32.20	20.04	2.06	0.00	6.96	5.70	3.9	7.94	23.5	4.8	0.00	0.00	0.00
7	22	76	12	23.	0.	******	38.07	3.45	0.00	19.28	16.04	16.0	7.98	21.5	4.1	5.00	1.81	0.00
7	22	76	13	2.	0.	******	39.77	3.49	0.00	18.24	14.92	16.0	8.08	21.5	4.6	5.00	1.67	0.00
7	22	76	14	0.	0.	61.62	42.78	3.37	0.00	16.70	13.60	16.0	8.00	21.5	4.5	5.00	1.62	0.00
7	22	76	15	7000.	230.	******	38.22	3.28	0.00	20.72	17.08	16.0	8.03	21.0	5.0	1.00	0.25	0.00
7	22	76	16	4960.	130.	******	38.84	3.51	0.00	19.60	15.40	16.0	8.08	21.0	3.9	1.00	0.15	0.00
7	22	76	17	1700.	110.	62.39	35.75	3.47	0.00	19.00	14.92	16.0	8.12	21.0	4.0	1.00	0.10	0.00
7	22	76	18	790.	33.	******	39.61	3.28	0.00	18.56	14.52	16.0	7.98	21.0	4.3	3.00	0.83	0.00
7	22	76	19	49.	0.	******	38.07	4.92	0.00	13.08	10.04	16.0	7.98	21.0	4.6	3.00	0.74	0.00
7	22	76	20	49.	0.	59.23	44.17	3.43	0.00	17.20	13.76	16.0	7.04	21.0	4.5	3.00	0.64	0.00
7	22	76	21	350.	2.	******	26.33	1.80	0.00	5.76	4.64	4.5	7.96	23.0	4.7	2.00	0.93	0.00
7	22	76	22	13.	0.	******	26.49	2.02	0.00	5.96	4.96	4.3	7.99	23.0	4.7	2.00	0.88	0.00
7	22	76	23	0.	0.	31.74	24.79	1.61	0.00	5.88	4.32	4.0	7.98	23.0	5.5	2.00	0.83	0.00
7	22	76	10	1100.	500.	90.27	10.39	3.26	0.00	29.68	24.52	18.0	8.00	23.0	4.3	0.00	0.00	0.00
7	22	76	12	4.	0.	******	45.79	3.16	0.00	21.96	17.48	18.0	7.84	23.0	4.7	10.00	4.66	0.00
7	22	76	13	2.	0.	******	47.10	3.26	0.00	21.92	17.64	18.0	7.86	23.0	4.4	10.00	4.61	0.00
7	22	76	14	0.	0.	74.98	45.79	3.30	0.00	20.16	16.04	18.0	7.85	23.0	3.6	10.00	4.51	0.00
7	22	76	15	130.	33.	******	44.25	3.89	0.00	22.84	18.36	18.0	7.98	23.0	3.9	2.00	0.78	0.00
7	22	76	16	49.	2.	******	45.64	3.37	0.00	19.84	16.00	17.0	7.97	23.0	3.8	2.00	0.59	0.00
7	22	76	17	5.	2.	69.27	40.23	3.45	0.00	18.16	13.88	17.0	7.99	23.0	3.9	2.00	0.47	0.00
7	22	76	18	70.	11.	******	38.30	3.26	0.00	17.12	13.60	17.0	7.97	23.0	4.0	4.00	1.08	0.00
7	22	76	19	2.	0.	******	37.92	3.61	0.00	17.76	12.84	17.0	8.02	23.0	3.9	4.00	0.96	0.00
7	22	76	20	0.	0.	66.41	34.31	3.59	0.00	16.36	13.60	17.0	7.98	23.0	3.7	4.00	0.83	0.00
7	22	76	21	26.	0.	******	25.25	1.89	0.00	5.36	4.16	4.5	7.92	23.0	4.0	3.00	1.32	0.00
7	22	76	22	0.	0.	******	26.62	2.00	0.00	5.68	4.48	4.2	7.98	23.0	3.8	3.00	1.18	0.00
7	22	76	23	0.	0.	33.45	33.60	2.02	0.00	5.76	4.60	4.5	7.92	23.0	3.8	3.00	1.08	0.00
7	27	76	10	54000.	790.	68.45	35.60	2.92	0.00	23.02	18.48	15.0	8.95	22.0	5.7	0.00	0.00	0.00
7	27	76	11	16000.	940.	29.69	26.64	1.49	0.00	4.80	3.12	4.5	7.98	25.0	3.5	0.00	0.00	0.00
7	27	76	12	23.	0.	******	37.45	2.29	0.00	18.92	15.40	14.0	8.18	21.0	0.5	5.00	2.15	0.00
7	27	76	13	13.	0.	******	35.60	1.90	0.00	19.40	15.56	14.0	8.19	22.0	3.8	5.00	2.03	0.00
7	27	76	14	7.	0.	58.92	34.52	2.18	0.00	18.28	14.44	15.0	8.19	22.0	3.9	5.00	2.00	0.00
7	27	76	15	24000.	700.	******	36.68	2.13	0.00	20.20	16.36	15.0	8.34	22.0	3.9	1.00	0.33	0.00
7	27	76	16	13000.	490.	******	35.14	1.92	0.00	21.08	17.24	15.0	8.36	22.0	4.2	1.00	0.28	0.00
7	27	76	17	9200.	230.	******	41.24	2.13	0.00	19.56	17.64	15.0	8.36	22.0	3.7	1.00	0.24	0.00
7	27	76	18	790.	70.	******	48.73	2.22	0.00	18.28	15.12	14.0	8.25	22.0	4.1	3.00	0.85	0.00
7	27	76	19	140.	21.	******	47.63	2.48	0.00	19.28	15.40	14.0	8.24	22.0	3.9	3.00	0.71	0.00
7	27	76	20	110.	8.	64.79	42.55	2.11	0.00	19.32	15.96	15.0	8.27	22.0	3.5	3.00	0.64	0.00
7	27	76	21	2200.	130.	******	27.88	1.41	0.00	4.00	2.88	4.6	8.12	23.0	3.2	1.00	0.57	0.00
7	27	76	22	240.	23.	******	33.51	1.76	0.00	4.76	3.16	4.5	8.02	25.0	3.0	1.00	0.50	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
7	27	76	23	34.	2.	28.65	26.49	1.71	0.00	4.44	2.60	4.8	8.12	25.0	3.1	1.00	0.45	0.00
7	27	76	10	3300.	330.	79.35	32.73	2.20	0.00	31.80	25.68	15.0	8.37	21.0	5.2	0.00	0.00	0.00
7	27	76	12	0.	0.	******	33.27	2.29	0.00	24.24	20.04	15.0	8.07	21.0	4.3	10.00	5.38	0.00
7	27	76	13	0.	0.	******	35.97	1.88	0.00	23.64	19.00	15.0	8.00	21.0	4.8	10.00	5.14	0.00
7	27	76	14	0.	0.	69.93	43.77	1.76	0.00	14.20	11.72	15.0	7.87	21.0	5.0	10.00	5.05	0.00
7	27	76	15	170.	5.	******	34.04	3.22	0.00	16.24	11.68	15.0	8.08	21.0	5.4	2.00	0.78	0.00
7	27	76	16	49.	7.	******	36.36	0.49	0.00	100.90	8.68	15.0	8.13	21.0	5.6	2.00	0.68	0.00
7	27	76	17	33.	0.	70.78	35.97	2.94	0.00	12.92	10.48	15.0	8.22	21.0	4.8	2.00	0.64	0.00
7	27	76	18	79.	5.	******	33.73	2.25	0.00	13.48	10.92	16.0	8.12	21.0	5.0	4.00	1.32	0.00
7	27	76	19	8.	0.	******	39.98	1.90	0.00	12.44	10.20	16.0	8.10	21.0	5.4	4.00	1.13	0.00
7	27	76	20	7.	0.	65.07	35.28	2.32	0.00	12.96	10.52	16.0	8.13	21.0	5.4	4.00	1.06	0.00
7	27	76	21	110.	20.	******	28.48	1.09	0.00	5.08	3.40	4.7	7.86	24.0	3.7	3.00	1.42	0.00
7	27	76	22	2.	0.	******	26.17	1.67	0.00	4.68	2.84	4.7	8.12	24.0	3.8	3.00	1.32	0.00
7	27	76	23	0.	0.	32.83	30.26	2.01	0.00	4.64	2.80	5.2	8.13	24.0	3.9	3.00	1.30	0.00
7	29	76	10	3300.	700.	70.67	35.53	0.72	0.00	23.90	19.66	13.0	9.00	23.0	11.1	0.00	0.00	0.00
7	29	76	11	74000.	200.	37.29	26.60	1.56	0.00	9.92	8.44	3.7	8.03	24.5	3.2	0.00	0.00	0.00
7	29	76	12	1100.	33.	******	39.28	0.71	0.00	19.56	16.56	12.0	8.89	23.0	7.1	5.00	2.31	0.00
7	29	76	13	8.	0.	******	41.58	0.73	0.00	18.40	15.48	14.0	8.90	23.0	6.7	5.00	2.17	0.00
7	29	76	14	0.	0.	59.65	37.75	0.69	0.00	18.44	15.04	12.0	8.90	23.0	8.1	5.00	2.10	0.00
7	29	76	15	3300.	330.	******	31.93	0.54	0.00	19.64	16.84	15.0	8.97	23.0	6.3	1.00	0.31	0.00
7	29	76	16	3300.	170.	******	31.70	0.42	0.00	18.60	15.60	11.0	8.97	23.0	6.6	1.00	0.21	0.00
7	29	76	17	3300.	70.	57.87	43.87	0.94	0.00	19.48	16.20	12.0	8.99	23.0	8.8	1.00	0.14	0.00
7	29	76	18	450.	70.	******	38.15	1.00	0.00	18.64	15.64	12.0	8.91	23.0	6.3	3.00	0.94	0.00
7	29	76	19	140.	33.	******	39.05	0.83	0.00	18.00	14.92	12.0	8.90	23.0	5.6	3.00	0.78	0.00
7	29	76	20	33.	8.	59.57	39.28	0.92	0.00	18.00	14.68	11.0	8.89	23.0	5.0	3.00	0.73	0.00
7	29	76	21	5.	0.	******	23.35	0.65	0.00	8.62	7.24	5.1	8.15	24.5	4.7	4.00	1.98	0.00
7	29	76	22	0.	0.	******	26.22	0.85	0.00	8.52	7.12	5.2	8.16	24.5	4.1	4.00	1.96	0.00
7	29	76	23	0.	0.	35.48	24.73	0.44	0.00	7.92	7.16	4.7	8.10	24.5	3.8	4.00	1.91	0.00
7	29	76	10	7000.	230.	98.16	46.17	0.83	0.00	32.88	27.08	13.0	9.03	23.0	10.6	0.00	0.00	0.00
7	29	76	12	2.	0.	******	43.87	0.02	0.00	19.44	16.36	14.0	8.43	23.0	7.2	20.00	2.48	0.42
7	29	76	13	0.	0.	******	50.00	0.63	0.00	18.52	16.12	15.0	8.40	23.0	7.1	20.00	2.26	0.19
7	29	76	14	0.	0.	68.38	42.96	0.83	0.00	18.00	15.08	13.0	8.40	23.0	7.2	20.00	2.12	0.02
7	29	76	15	700.	49.	******	43.72	0.77	0.00	22.00	17.48	11.0	8.91	23.0	6.8	2.00	0.87	0.00
7	29	76	16	230.	13.	******	40.05	0.79	0.00	22.16	18.20	12.0	8.94	23.0	6.8	2.00	0.83	0.00
7	29	76	17	170.	5.	69.14	40.05	0.75	0.00	19.48	16.20	13.0	8.92	23.0	6.8	2.00	0.80	0.00
7	29	76	18	170.	33.	******	41.58	0.92	0.00	19.16	16.16	13.0	8.90	23.0	7.0	4.00	1.34	0.00
7	29	76	19	13.	2.	******	38.51	0.48	0.00	18.84	15.72	12.0	8.92	23.0	7.4	4.00	1.27	0.00
7	29	76	20	11.	0.	70.57	41.71	0.69	0.00	18.56	14.92	11.0	8.90	23.0	6.9	4.00	1.23	0.00
7	29	76	21	0.	0.	******	33.92	0.52	0.00	9.16	7.80	4.9	8.07	24.0	4.1	6.00	3.07	0.00
7	29	76	22	0.	0.	******	30.86	0.52	0.00	9.76	9.64	4.6	8.09	24.0	4.4	6.00	2.97	0.00
7	29	76	23	0.	0.	45.18	37.75	0.48	0.00	7.96	7.48	5.2	8.07	24.0	4.4	6.00	2.92	0.00
8	3	76	10	1400.	200.	81.97	46.83	1.88	0.00	22.72	18.64	12.0	8.43	21.5	3.6	0.00	0.00	0.00
8	3	76	11	2700.	200.	27.01	28.95	1.25	0.00	6.08	5.18	5.3	7.94	23.1	2.9	0.00	0.00	0.00
8	3	76	12	0.	0.	******	46.72	1.58	0.00	20.52	16.40	18.0	7.82	21.9	3.3	20.00	10.67	0.00
8	3	76	13	0.	0.	******	49.72	1.76	0.00	15.64	14.08	17.0	7.91	21.5	3.5	20.00	10.48	0.00
8	3	76	14	0.	0.	65.03	40.72	2.45	0.00	15.56	13.00	16.0	7.76	21.7	3.2	20.00	10.10	0.00
8	3	76	15	140.	20.	******	44.10	2.18	0.00	16.24	14.94	15.0	8.50	21.5	3.6	2.00	0.86	0.00
8	3	76	16	33.	2.	******	37.33	1.51	0.00	16.36	13.32	14.0	8.33	21.3	3.2	2.00	0.76	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
8	3	76	17	8.	0.	55.03	41.94	1.58	0.00	15.56	13.24	15.0	8.37	21.3	3.3	2.00	0.67	0.00
8	3	76	18	230.	5.	******	36.56	1.56	0.00	17.28	14.44	15.0	8.25	21.8	3.6	4.00	1.29	0.00
8	3	76	19	5.	0.	******	42.71	1.60	0.00	14.92	12.16	14.0	8.29	21.5	3.2	4.00	1.19	0.00
8	3	76	20	17.	0.	56.34	38.33	2.43	0.00	13.76	11.40	14.0	8.31	21.5	3.0	4.00	1.14	0.00
8	3	76	21	0.	0.	******	26.17	1.85	0.00	5.84	4.72	5.3	7.93	23.0	3.6	4.00	2.17	0.00
8	3	76	22	0.	0.	******	29.64	1.36	0.00	5.72	4.96	5.4	7.91	22.9	3.0	4.00	2.16	0.00
8	3	76	23	0.	0.	26.60	25.01	1.05	0.00	5.96	5.04	6.2	8.01	23.0	3.1	4.00	2.10	0.00
8	3	76	10	1400.	200.	112.90	40.33	3.51	0.00	34.20	27.36	21.0	8.29	21.0	3.5	0.00	0.00	0.00
8	3	76	12	0.	0.	******	37.33	2.31	0.00	21.16	16.88	18.0	7.89	21.0	4.0	15.00	9.43	0.00
8	3	76	13	0.	1.	******	39.56	2.03	0.00	17.36	14.16	17.0	7.84	21.0	4.1	15.00	9.14	0.00
8	3	76	14	0.	0.	75.04	38.87	2.11	0.00	18.28	13.88	17.0	7.86	21.0	4.2	15.00	8.95	0.00
8	3	76	15	1400.	20.	******	39.25	2.63	0.00	21.76	16.92	16.0	8.29	21.0	3.9	1.00	0.33	0.00
8	3	76	16	1400.	20.	******	40.17	2.29	0.00	21.00	16.72	16.0	8.33	21.0	3.8	1.00	0.24	0.00
8	3	76	17	1400.	5.	64.42	40.79	2.13	0.00	20.24	16.08	16.0	8.32	21.0	4.0	1.00	0.19	0.00
8	3	76	18	0.	0.	******	33.48	2.14	0.00	20.60	16.60	17.0	8.29	21.0	4.0	5.00	1.76	0.00
8	3	76	19	0.	0.	******	40.25	2.67	0.00	18.28	15.00	17.0	8.20	21.0	4.5	5.00	1.57	0.00
8	3	76	20	0.	0.	66.57	36.02	2.14	0.00	18.36	14.84	17.0	8.18	21.0	4.4	5.00	1.48	0.00
8	3	76	21	0.	0.	******	18.93	1.30	0.00	5.40	5.40	5.6	7.85	22.0	3.7	5.00	2.67	0.00
8	3	76	22	0.	0.	******	17.32	1.41	0.00	5.44	4.32	5.8	7.88	22.0	4.1	5.00	2.48	0.00
8	3	76	23	0.	0.	24.01	18.32	1.23	0.00	5.72	4.88	5.6	7.40	22.0	4.1	5.00	2.45	0.00
8	5	76	10	1100.	130.	57.32	34.44	1.75	0.00	19.88	16.26	15.0	8.33	20.0	3.6	0.00	0.00	0.00
8	5	76	11	11000.	200.	34.75	21.53	0.76	0.00	5.10	4.30	4.2	8.43	22.0	2.7	0.00	0.00	0.00
8	5	76	12	5.	0.	******	41.03	1.52	0.00	14.08	11.48	13.0	8.10	19.5	4.5	5.00	2.62	0.00
8	5	76	13	0.	0.	******	36.22	1.57	0.00	13.20	11.28	13.0	8.17	19.5	3.7	5.00	2.57	0.00
8	5	76	14	0.	0.	68.80	35.91	1.52	0.00	13.16	11.00	14.0	8.18	19.5	4.1	5.00	2.52	0.00
8	5	76	15	940.	20.	******	36.38	1.78	0.00	14.88	12.04	14.0	8.29	19.5	3.4	1.00	0.26	0.00
8	5	76	16	450.	20.	******	35.99	1.57	0.00	13.28	10.92	12.0	8.29	19.5	3.8	1.00	0.19	0.00
8	5	76	17	330.	5.	55.15	35.84	1.63	0.00	13.72	10.96	12.0	8.28	19.5	4.2	1.00	0.16	0.00
8	5	76	18	790.	9.	******	41.11	1.26	0.00	12.80	10.24	13.0	8.20	19.5	3.8	3.00	0.91	0.00
8	5	76	19	130.	0.	******	34.91	1.36	0.00	13.56	10.96	13.0	8.19	19.5	3.7	3.00	0.86	0.00
8	5	76	20	170.	0.	48.09	40.41	1.47	0.00	13.04	10.88	12.0	8.23	19.5	4.6	3.00	0.84	0.00
8	5	76	21	11.	0.	******	21.49	0.79	0.00	4.76	4.14	4.4	7.89	22.0	4.0	4.00	1.92	0.00
8	5	76	22	2.	0.	******	21.56	0.84	0.00	4.80	4.16	4.5	7.87	22.0	3.3	4.00	1.87	0.00
8	5	76	23	0.	0.	28.70	24.82	0.84	0.00	4.16	4.16	4.4	7.92	22.0	3.1	4.00	1.85	0.00
8	5	76	21	0.	0.	******	23.97	1.05	0.00	5.52	4.76	4.6	7.80	22.0	3.1	10.00	6.12	0.00
8	5	76	22	0.	0.	******	21.56	0.94	0.00	5.16	3.96	4.4	7.78	22.0	3.3	10.00	5.98	0.00
8	5	76	23	0.	0.	37.07	23.89	0.94	0.00	5.40	4.64	5.4	7.76	22.0	3.6	10.00	5.89	0.00
8	10	76	11	16000.	3500.	32.25	25.70	1.94	0.00	5.54	4.52	4.5	7.88	21.0	2.8	0.00	0.00	0.00
8	10	76	12	13.	0.	******	36.82	2.19	0.00	11.80	7.36	12.0	7.98	20.0	2.9	5.00	2.17	0.00
8	10	76	13	7.	0.	******	36.43	2.40	0.00	11.00	9.20	11.0	7.97	19.9	3.0	5.00	2.12	0.00
8	10	76	14	2.	0.	62.56	41.24	2.31	0.00	10.12	8.52	11.0	8.00	19.9	3.1	5.00	2.03	0.00
8	10	76	15	1300.	20.	******	42.25	2.84	0.00	11.32	9.68	11.0	8.10	20.0	3.1	1.00	0.28	0.00
8	10	76	16	330.	20.	******	41.71	2.56	0.00	10.28	9.08	11.0	8.08	19.9	3.0	1.00	0.24	0.00
8	10	76	17	330.	2.	55.81	33.49	2.33	0.00	9.76	9.20	11.0	8.12	19.9	2.7	1.00	0.19	0.00
8	10	76	18	170.	22.	******	40.93	2.44	0.00	9.44	8.52	11.0	8.03	20.0	3.1	3.00	0.94	0.00
8	10	76	19	17.	0.	******	41.47	2.12	0.00	10.76	9.04	11.0	8.12	20.0	3.1	3.00	0.83	0.00
8	10	76	20	5.	0.	67.29	39.92	2.48	0.00	18.68	8.76	11.0	8.03	20.0	2.9	3.00	0.75	0.00
8	10	76	21	3300.	330.	******	33.18	2.09	0.00	5.00	4.20	4.8	7.95	20.8	3.3	1.00	0.61	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
8	10	76	22	1100.	130.	******	30.85	1.76	0.00	5.28	4.36	4.8	8.02	20.7	3.1	1.00	0.52	0.00
8	10	76	23	110.	20.	37.60	29.53	1.61	0.00	4.32	2.04	5.0	8.01	20.8	3.1	1.00	0.47	0.00
8	10	76	10	940.	20.	68.68	40.00	3.13	0.00	18.28	15.68	12.0	7.96	21.0	3.0	0.00	0.00	0.00
8	10	76	12	0.	0.	******	38.61	0.19	0.00	9.24	5.44	13.0	7.44	21.0	3.4	30.00	2.12	0.45
8	10	76	13	0.	0.	******	42.09	0.15	0.00	10.16	8.88	14.0	7.40	21.0	3.4	30.00	1.82	0.20
8	10	76	14	0.	0.	53.95	38.84	0.19	0.00	10.48	9.00	15.0	7.62	21.0	3.2	30.00	1.60	0.20
8	10	76	15	33.	2.	******	41.85	3.59	0.00	12.16	10.00	12.0	8.02	21.0	3.3	2.00	0.99	0.00
8	10	76	16	0.	0.	******	50.47	2.69	0.00	12.28	10.44	11.0	8.02	21.0	3.2	2.00	0.85	0.00
8	10	76	17	0.	0.	52.81	44.81	2.82	0.00	11.60	10.28	11.0	8.10	21.0	3.1	2.00	0.73	0.00
8	10	76	18	240.	3.	******	47.13	2.50	0.00	14.28	12.16	12.0	8.03	21.0	3.4	4.00	1.42	0.00
8	10	76	19	5.	0.	******	41.71	2.88	0.00	12.32	9.88	11.0	8.03	21.0	3.4	4.00	1.18	0.00
8	10	76	20	2.	0.	61.09	42.00	3.34	0.00	13.40	10.36	12.0	8.04	21.0	3.6	4.00	1.08	0.00
8	10	76	21	7900.	170.	******	30.85	1.76	0.00	6.40	5.20	5.5	7.92	21.0	2.7	2.00	1.27	0.00
8	10	76	22	130.	5.	******	32.56	1.76	0.00	5.68	4.88	5.9	7.90	21.0	2.9	2.00	1.18	0.00
8	10	76	23	0.	0.	40.16	33.64	1.77	0.00	6.32	5.08	5.5	7.93	21.0	2.8	2.00	1.08	0.00
8	12	76	10	3300.	50.	58.11	37.84	3.06	0.00	16.90	13.58	10.0	7.88	19.5	2.6	0.00	0.00	0.00
8	12	76	11	79000.	200.	33.92	27.91	2.47	0.00	4.12	3.34	3.7	7.92	21.5	2.2	0.00	0.00	0.00
8	12	76	12	33.	0.	******	36.93	2.92	0.00	11.32	9.16	11.0	8.12	19.5	3.3	5.00	2.03	0.00
8	12	76	13	2.	0.	******	40.69	2.92	0.00	8.52	6.52	10.0	8.02	19.0	2.9	5.00	1.99	0.00
8	12	76	14	0.	0.	51.22	36.10	2.84	0.00	8.92	7.24	10.0	8.12	19.0	3.9	5.00	1.94	0.00
8	12	76	15	3100.	20.	******	38.81	3.08	0.00	10.08	8.24	10.0	8.20	19.5	2.9	1.00	0.26	0.00
8	12	76	16	1700.	20.	******	41.29	3.01	0.00	8.84	6.84	8.6	8.20	19.0	3.4	1.00	0.19	0.00
8	12	76	17	2200.	20.	51.07	38.59	6.00	0.00	8.60	6.84	8.5	8.25	19.0	3.7	1.00	0.14	0.00
8	12	76	18	490.	3.	******	32.42	2.72	0.00	8.32	6.80	8.4	8.23	19.5	3.5	3.00	0.96	0.00
8	12	76	19	79.	0.	******	38.21	2.88	0.00	7.84	6.32	8.5	8.20	19.5	3.3	3.00	0.93	0.00
8	12	76	20	49.	0.	42.05	41.44	2.32	0.00	8.08	6.52	9.3	8.20	19.5	3.9	3.00	0.91	0.00
8	12	76	21	7900.	70.	******	38.29	3.06	0.00	4.04	2.40	5.4	8.12	21.5	3.3	1.00	0.61	0.00
8	12	76	22	700.	20.	******	36.18	2.80	0.00	4.16	3.20	4.7	8.13	21.5	3.2	1.00	0.54	0.00
8	12	76	23	110.	2.	29.08	23.24	2.52	0.00	3.96	3.28	4.7	8.14	21.5	2.7	1.00	0.51	0.00
8	12	76	10	7900.	40.	63.18	38.44	2.80	0.00	10.52	8.88	11.0	8.00	20.0	2.6	0.00	0.00	0.00
8	12	76	12	0.	0.	******	42.20	2.72	0.00	9.08	6.96	10.0	7.80	20.0	3.6	20.00	9.91	0.60
8	12	76	13	0.	0.	******	39.64	2.94	0.00	8.00	6.56	10.0	7.78	20.0	3.6	20.00	9.77	0.48
8	12	76	14	0.	0.	51.97	42.20	2.50	0.00	8.32	6.80	10.0	7.82	20.0	3.7	20.00	9.58	0.28
8	12	76	15	27.	2.	******	40.54	2.86	0.00	9.24	6.96	11.0	8.06	20.0	2.7	2.00	0.98	0.00
8	12	76	16	2.	0.	******	40.24	2.94	0.00	8.76	6.60	10.0	8.12	20.0	2.8	2.00	0.96	0.00
8	12	76	17	2.	0.	57.69	40.69	2.94	0.00	9.16	7.16	11.0	8.16	20.0	2.4	2.00	0.91	0.00
8	12	76	18	27.	0.	******	38.59	2.96	0.00	9.68	7.96	10.0	8.08	20.0	2.9	4.00	1.26	0.00
8	12	76	19	0.	0.	******	38.96	2.90	0.00	8.84	6.60	10.0	8.07	20.0	3.1	4.00	1.19	0.00
8	12	76	20	5.	0.	54.75	38.90	2.98	0.00	8.84	6.48	11.0	8.06	20.0	3.1	4.00	1.14	0.00
8	12	76	21	440.	11.	******	26.40	2.48	0.00	3.76	3.32	4.3	7.91	21.0	5.4	2.00	1.29	0.00
8	12	76	22	4.	0.	******	25.63	2.38	0.00	3.68	3.32	4.6	7.99	21.0	5.3	2.00	1.21	0.00
8	12	76	23	0.	0.	31.82	29.71	2.54	0.00	3.56	3.28	4.2	8.00	21.0	5.8	2.00	1.17	0.00
8	17	76	10	1700.	50.	54.96	36.65	4.27	0.00	12.82	9.30	10.0	8.42	20.0	4.0	0.00	0.00	0.00
8	17	76	11	2300.	500.	32.45	26.92	2.97	0.00	3.62	3.02	3.7	7.92	20.0	6.1	0.00	0.00	0.00
8	17	76	12	0.	0.	******	33.12	3.65	0.00	9.76	8.28	8.6	7.95	20.0	4.5	10.00	4.86	0.00
8	17	76	13	0.	0.	******	33.34	3.88	0.00	8.56	7.04	8.9	8.00	20.0	4.6	10.00	4.81	0.00
8	17	76	14	0.	0.	46.49	30.89	3.49	0.00	8.98	6.64	9.4	8.02	20.0	4.9	10.00	4.77	0.00
8	17	76	15	940.	50.	******	35.27	3.83	0.00	10.36	9.52	8.9	8.10	20.0	4.7	1.00	0.32	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DC MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
8	17	76	16	230.	50.	******	32.23	3.99	0.00	9.16	8.04	8.6	8.09	20.0	4.8	1.00	0.28	0.00
8	17	76	17	170.	20.	51.53	35.50	3.83	0.00	9.92	7.80	9.1	8.11	20.0	4.9	1.00	0.23	0.00
8	17	76	18	230.	0.	******	36.09	3.65	0.00	8.84	6.92	8.7	8.03	20.0	5.0	3.00	1.02	0.00
8	17	76	19	8.	0.	******	31.63	3.60	0.00	8.40	6.32	9.2	8.01	20.0	4.8	3.00	0.97	0.00
8	17	76	20	17.	0.	36.83	31.04	3.62	0.00	8.56	6.36	8.8	8.10	20.0	4.6	3.00	0.93	0.00
8	17	76	21	330.	5.	******	30.89	2.20	0.00	3.72	2.80	4.0	7.93	21.0	6.3	3.00	1.67	0.00
8	17	76	22	8.	0.	******	26.58	2.73	0.00	3.44	3.12	3.7	7.90	21.0	6.5	3.00	1.57	0.00
8	17	76	23	0.	0.	31.63	26.26	2.87	0.00	3.28	2.84	4.1	7.96	21.0	6.4	3.00	1.53	0.00
8	17	76	10	1300.	20.	62.60	32.27	3.53	0.00	18.65	15.20	8.8	7.87	20.0	4.0	0.00	0.00	0.00
8	17	76	12	0.	0.	******	32.15	2.41	0.00	9.56	7.56	9.8	7.43	20.0	4.1	30.00	17.59	0.00
8	17	76	13	0.	0.	******	31.56	2.23	0.00	9.16	7.56	10.0	7.49	20.0	4.2	30.00	17.04	0.00
8	17	76	14	0.	0.	45.74	35.27	2.16	0.00	8.96	7.80	11.0	7.70	20.0	4.3	30.00	16.85	0.00
8	17	76	15	13.	0.	******	35.35	3.56	0.00	11.00	9.60	9.2	7.98	20.0	4.0	2.00	1.11	0.00
8	17	76	16	2.	0.	******	33.86	3.37	0.00	9.36	7.60	8.6	7.92	20.0	3.8	2.00	1.02	0.00
8	17	76	17	5.	0.	51.68	28.66	3.65	0.00	6.96	5.76	9.3	7.99	20.0	4.2	2.00	0.97	0.00
8	17	76	18	11.	2.	******	33.64	3.42	0.00	10.28	8.16	9.4	7.91	20.0	4.1	4.00	1.48	0.00
8	17	76	19	0.	0.	******	33.86	3.65	0.00	9.24	6.64	9.2	7.95	20.0	4.3	4.00	1.37	0.00
8	17	76	20	0.	0.	85.77	37.57	3.33	0.00	8.12	6.60	9.0	7.93	20.0	4.0	4.00	1.30	0.00
8	17	76	21	0.	0.	******	24.88	1.81	0.00	4.08	3.80	3.7	7.52	21.0	6.5	20.00	12.96	0.00
8	17	76	22	0.	0.	******	23.47	1.97	0.00	4.84	3.68	3.6	7.60	21.0	6.4	20.00	12.87	0.00
8	17	76	23	0.	0.	31.63	21.98	1.77	0.00	3.72	3.72	4.2	7.49	21.0	6.5	20.00	12.78	0.00
8	19	76	10	460.	80.	59.43	31.26	4.09	0.00	15.78	11.64	11.0	8.27	19.0	4.5	0.00	0.00	0.00
8	19	76	11	7900.	500.	25.24	23.41	3.02	0.00	4.16	2.72	3.6	8.09	21.0	5.8	0.00	0.00	0.00
8	19	76	12	2.	0.	******	32.67	4.10	0.00	13.64	9.96	13.0	7.95	18.5	4.6	10.00	6.40	0.00
8	19	76	13	2.	0.	******	37.40	4.35	0.00	41.92	8.84	12.0	7.98	18.5	4.8	10.00	6.31	0.00
8	19	76	14	0.	0.	44.64	33.26	3.92	0.00	11.56	9.32	11.0	7.89	18.0	5.3	10.00	6.26	0.00
8	19	76	15	460.	20.	******	30.08	4.28	0.00	12.52	9.76	11.0	8.12	18.5	4.9	1.00	0.30	0.00
8	19	76	16	460.	20.	******	27.94	4.08	0.00	12.20	9.96	10.0	8.18	18.5	4.9	1.00	0.21	0.00
8	19	76	17	460.	20.	66.52	29.56	4.41	0.00	12.44	9.32	10.0	8.16	18.5	5.4	1.00	0.18	0.00
8	19	76	18	180.	2.	******	32.45	3.76	0.00	11.72	8.28	11.0	8.03	19.0	4.8	3.00	1.00	0.00
8	19	76	19	130.	0.	******	31.41	4.26	0.00	9.80	7.12	11.0	8.06	19.0	5.1	3.00	0.91	0.00
8	19	76	20	23.	0.	45.53	31.41	3.94	0.00	11.76	8.68	11.0	8.12	19.0	5.8	3.00	0.86	0.00
8	19	76	21	0.	0.	******	22.17	2.34	0.00	3.56	2.28	4.4	7.78	21.0	4.9	10.00	7.20	0.00
8	19	76	22	0.	0.	******	21.43	2.39	0.00	3.92	2.32	3.5	7.77	20.5	5.0	10.00	7.01	0.00
8	19	76	23	0.	0.	25.20	21.58	2.12	0.00	3.88	2.32	4.0	7.91	20.5	5.9	10.00	6.82	0.00
8	19	76	10	1400.	110.	76.96	30.60	4.39	0.00	24.00	18.36	14.0	8.10	19.5	4.2	0.00	0.00	0.00
8	19	76	12	0.	0.	******	22.76	3.67	0.00	18.60	14.20	13.0	7.72	19.5	4.4	20.00	13.46	0.00
8	19	76	13	0.	0.	******	27.94	3.65	0.00	16.44	12.00	12.0	7.69	19.5	4.2	20.00	13.18	0.00
8	19	76	14	0.	0.	56.17	27.42	3.72	0.00	16.72	12.00	13.0	7.70	19.5	4.5	20.00	13.08	0.00
8	19	76	15	350.	2.	******	29.05	3.38	0.00	19.08	13.76	13.0	8.01	19.5	4.0	2.00	0.93	0.00
8	19	76	16	5.	0.	******	31.78	3.96	0.00	16.24	12.00	12.0	8.01	19.5	4.3	2.00	0.89	0.00
8	19	76	17	9.	0.	47.30	34.15	4.39	0.00	14.80	10.64	10.0	8.02	19.5	4.4	2.00	0.84	0.00
8	19	76	18	240.	2.	******	28.97	4.23	0.00	16.68	12.32	13.0	8.01	19.5	3.5	4.00	1.21	0.00
8	19	76	19	14.	0.	******	29.27	4.28	0.00	17.88	10.80	12.0	8.04	19.5	4.4	4.00	1.14	0.00
8	19	76	20	11.	0.	45.68	27.20	3.87	0.00	15.16	11.36	11.0	8.02	19.5	4.3	4.00	1.10	0.00
8	19	76	21	0.	0.	******	19.22	1.06	0.00	4.08	2.32	4.2	7.61	20.5	4.6	20.00	9.58	0.00
8	19	76	22	0.	0.	******	17.00	0.99	0.00	3.92	2.80	4.1	7.72	20.5	4.8	20.00	9.44	0.00
8	19	76	23	0.	0.	26.90	19.36	1.17	0.00	3.76	2.60	4.1	7.65	20.5	4.8	20.00	9.25	0.00

TABLE A-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SULFIDE MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L	APPLIED CL2 MG/L	TOTAL RESIDUAL MG/L	FREE RESIDUAL MG/L
8	24	76	10	7900.	700.	73.03	34.51	2.40	0.00	32.93	28.69	18.0	8.53	20.0	4.5	0.00	0.00	0.00
8	24	76	11	4900.	330.	35.05	28.06	0.72	0.00	6.40	6.20	6.2	8.57	19.5	5.0	0.00	0.00	0.00
8	24	76	12	170.	11.	******	39.99	2.78	0.00	30.10	27.50	17.0	8.40	20.0	4.5	5.00	2.61	0.00
8	24	76	13	5.	2.	******	******	2.13	0.00	21.30	19.90	15.0	8.35	20.0	4.5	5.00	2.48	0.00
8	24	76	14	13.	0.	63.15	36.13	2.50	0.00	20.56	18.20	16.0	8.34	20.0	3.7	5.00	2.43	0.00
8	24	76	15	3300.	490.	******	32.42	2.24	0.00	21.00	19.12	16.0	8.46	20.0	4.5	1.00	0.18	0.00
8	24	76	16	2300.	250.	******	38.68	2.76	0.00	22.80	21.05	16.0	8.56	20.0	4.7	1.00	0.09	0.00
8	24	76	17	2300.	110.	69.40	35.36	2.26	0.00	24.50	21.90	16.0	8.42	20.0	3.9	1.00	0.05	0.00
8	24	76	18	2400.	170.	******	35.36	2.22	0.00	19.20	17.80	16.0	8.35	20.0	4.7	3.00	0.83	0.00
8	24	76	19	240.	3.	******	35.90	2.20	0.00	23.25	21.40	15.0	8.39	20.0	4.8	3.00	0.69	0.00
8	24	76	20	920.	4.	65.23	34.35	2.11	0.00	18.60	16.80	15.0	8.40	20.0	3.6	3.00	0.55	0.00
8	24	76	21	2800.	79.	******	24.55	1.71	0.00	5.28	6.12	6.7	8.47	20.0	4.3	1.00	0.46	0.00
8	24	76	22	330.	23.	******	33.04	0.63	0.00	4.60	6.04	6.8	8.50	20.0	5.0	1.00	0.39	0.00
8	24	76	23	130.	7.	36.13	24.55	0.59	0.00	6.32	6.16	6.5	8.54	20.0	4.6	1.00	0.32	0.00
8	24	76	10	13000.	940.	96.35	38.60	2.03	0.00	45.10	41.30	17.0	8.50	21.0	6.6	0.00	0.00	0.00
8	24	76	12	2.	2.	******	43.85	0.12	0.00	23.24	21.56	18.0	7.53	21.0	6.9	30.00	3.21	0.55
8	24	76	13	0.	0.	******	39.84	0.04	0.00	23.10	21.80	16.0	7.56	21.0	6.0	30.00	2.89	0.35
8	24	76	14	0.	0.	70.87	41.15	0.02	0.00	22.35	21.50	16.0	7.52	21.0	6.9	30.00	2.39	0.25
8	24	76	15	1100.	140.	******	39.84	1.61	0.00	27.90	26.85	15.0	8.49	21.0	6.8	2.00	0.78	0.00
8	24	76	16	70.	8.	******	38.60	1.79	0.00	25.50	22.10	15.0	8.40	21.0	6.7	2.00	0.69	0.00
8	24	76	17	70.	0.	75.50	39.99	1.93	0.00	21.70	23.85	16.0	8.38	21.0	6.9	2.00	0.64	0.00
8	24	76	18	330.	75.	******	37.67	1.87	0.00	27.20	25.80	16.0	8.38	21.0	6.6	4.00	1.19	0.00
8	24	76	19	49.	0.	******	42.38	2.74	0.00	23.50	21.25	14.0	8.35	21.0	6.7	4.00	1.10	0.00
8	24	76	20	23.	0.	80.90	38.37	1.93	0.00	22.70	21.55	15.0	8.36	21.0	6.8	4.00	1.01	0.00
8	24	76	21	79.	2.	******	25.86	0.81	0.00	6.12	6.04	6.7	8.28	21.0	5.0	2.00	1.19	0.00
8	24	76	22	5.	0.	******	26.87	0.59	0.00	6.98	6.32	6.7	8.28	21.0	5.1	2.00	1.15	0.00
8	24	76	23	0.	0.	31.50	24.55	0.96	0.00	8.28	6.44	6.1	8.30	21.0	5.0	2.00	1.10	0.00

A ZERO FOR MPN TC AND MPN FC INDICATES A COUNT OF LESS THAN TWO PER 100 ML. DATA NOT TAKEN IS REPRESENTED BY ****.

APPENDIX B

SUMMARY OF REGRESSION STATISTICS

TABLE B-1. SUMMARY OF REGRESSION STATISTICS

Figure		Slope	Intercept	Correlation Coefficient	Mean Squares		Degrees of Freedom	
					Model	Error	Model	Error
19		0.222	1.381	0.814	322.38	10.951	1	15
18	L_1	0.024	0	0.519	8.167	11.096	1	2
18	L_2	0.059	0	0.980	54.875	0.754	1	3
18	L_3	0.141	0	0.899	364.34	28.615	1	3
18	H_1	0.065	0	0.940	77.069	3.375	1	3
18	H_2	0.059	0	0.835	63.132	9.127	1	3
18	H_3	0.172	0	0.950	537.72	19.386	1	3
24		1.019	0	0.953	95105.6	57.630	1	167
25		0.978	0	0.974	701818.	64.161	1	585
30		0.649	0	0.883	4835.39	8.219	1	167
31		0.650	0	0.947	208690.	41.242	1	585
32		4.692	-2.948	0.547	1572.69	92.178	1	40
36	θ_1	-1.139	0	0.922	66.918	0.302	1	39
36	θ_2	-1.807	0	0.939	124.614	0.445	1	38
36	θ_3	-2.161	0	0.908	158.162	0.905	1	37
40	θ_1	-1.115	0	0.897	41.994	0.363	1	28
40	θ_2	-1.764	0	0.884	66.106	0.743	1	25
40	θ_3	-1.811	0	0.813	55.074	1.410	1	20
44	θ_1	-0.726	0	0.876	552.766	1.042	1	161
44	θ_2	-0.992	0	0.843	545.390	1.627	1	137
44	θ_3	-1.098	0	0.823	595.194	2.110	1	134
48	θ_1	-0.881	0	0.883	314.131	0.721	1	123
48	θ_2	-1.237	0	0.844	278.975	1.259	1	89
48	θ_3	-1.399	0	0.804	274.744	1.862	1	81
49		0.509	0	0.954	1032.70	0.610	1	167
50		0.491	0	0.904	10186.6	3.896	1	585
54	θ_1	0.534	0.062	0.933	245.001	0.674	1	54
54	θ_2	0.505	0.007	0.933	219.241	0.605	1	54
54	θ_3	0.479	0.010	0.932	196.954	0.554	1	54
58	θ_1	0.507	0.139	0.847	1911.03	3.868	1	194
58	θ_2	0.481	0.098	0.833	1721.54	3.940	1	193
58	θ_3	0.460	0.076	0.822	1557.94	3.861	1	193
66	T_1	0.369	-0.918	0.813	460.512	2.035	1	116
66	T_2	0.468	0.044	0.957	742.084	0.788	1	87
66	T_3	0.474	0.375	0.933	1244.27	1.371	1	134
66	T_4	0.534	0.458	0.851	3460.08	4.328	1	305
71	T_1	0.616	-0.128	0.986	52.435	0.046	1	31
71	T_2	0.725	-0.140	0.957	62.071	0.132	1	43
71	T_3	0.595	-0.036	0.977	34.860	0.043	1	39
71	T_4	0.501	-0.090	0.978	522.585	1.072	1	79
C-18	V_1	0.435	0	0.892	158.864	0.602	1	68
C-18	V_2	0.552	0	0.982	887.625	0.401	1	80
C-18	V_3	0.239	0	0.492	13.342	0.100	1	17
C-24	V_1	0.492	0	0.977	998.400	0.893	1	53
C-24	V_2	0.403	0	0.894	1909.94	3.958	1	121
C-24	V_3	0.570	0	0.887	1049.97	3.197	1	89
C-24	V_4	0.459	0	0.923	2861.54	2.991	1	166
C-24	V_5	0.622	0	0.918	3656.13	4.489	1	152

θ_1 = 18 min. contact time.
θ_2 = 35 min. contact time.
θ_3 = 50 min. contact time.
V_1 = 0 - 5 mg/l VSS.
V_2 = 5 - 10 mg/l VSS.
V_3 = 10 - 20 mg/l VSS.
V_4 = 20 - 30 mg/l VSS.
V_5 = > 30 mg/l VSS.

A_1 = 0 - 0.5 mg/l NH_3-N.
A_2 = 0.5 - 1.0 mg/l NH_3-N.
A_3 = 1.0 - 2.0 mg/l NH_3-N.
A_4 = 2.0 - 4.0 mg/l NH_3-N.
A_5 = > 4.0 mg/l NH_3-N.
T_1 = 0° - 5° C.
T_2 = 5° - 10° C.
T_3 = 10° - 15° C.
T_4 = > 15°C.

L_1 = low initial SCOD at 4.2 Cl_2 dose.
L_2 = low initial SCOD at 16.9 Cl_2 dose.
L_3 = low initial SCOD at 50.8 Cl_2 dose.
H_1 = high initial SCOD at 4.2 Cl_2 dose.
H_2 = high initial SCOD at 16.9 Cl_2 dose.
H_3 = high initial SCOD at 50.8 Cl_2 dose.

[a] Is not significant to 5 percent confidence interval or better.

APPENDIX C
SOLUBLE COD DATA AND EFFECTS OF VOLATILE SUSPENDED SOLIDS ON TOTAL CHLORINE RESIDUAL

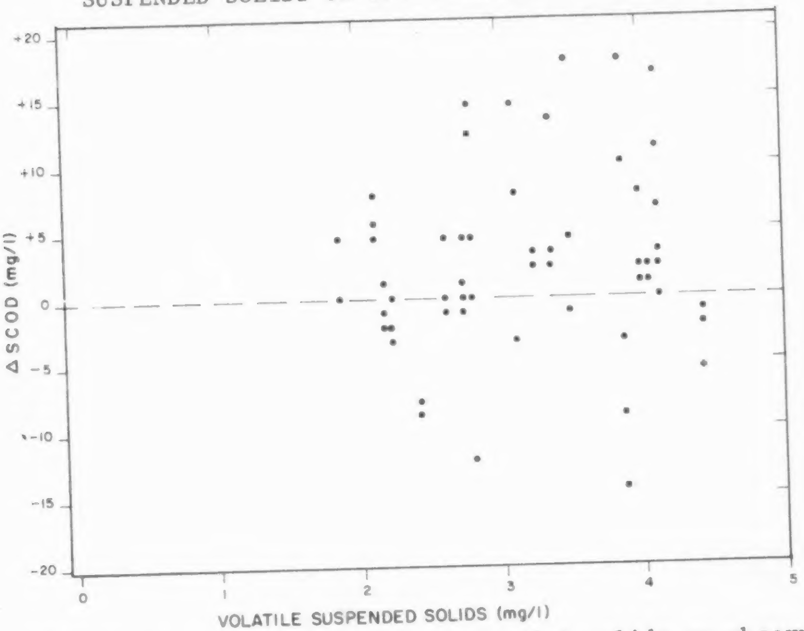

Figure C-1. Effects of 0-5 mg/l volatile suspended solids on observed changes changes in soluble COD between chlorinated and unclorinated filtered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

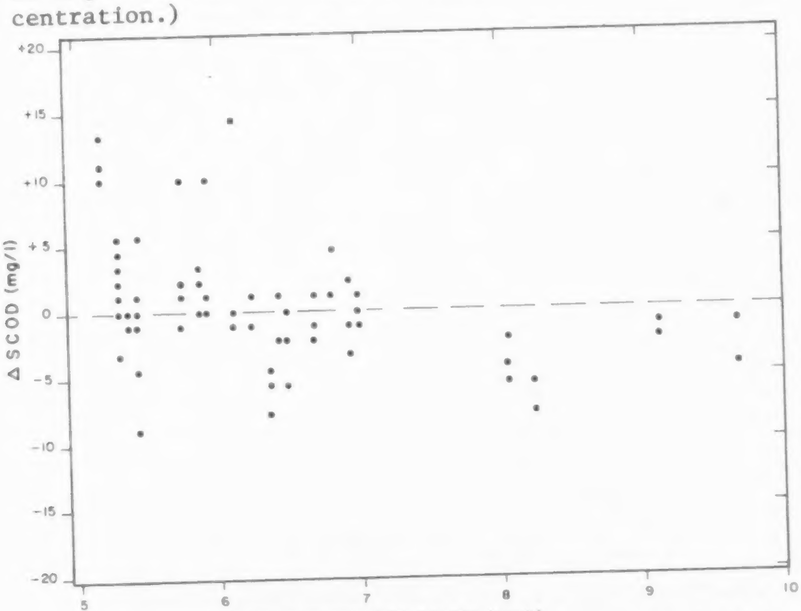

Figure C-2. Effects of 5-10 mg/l volatile suspended solids on observed changes in soluble COD between chlorinated and unclorinated filtered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

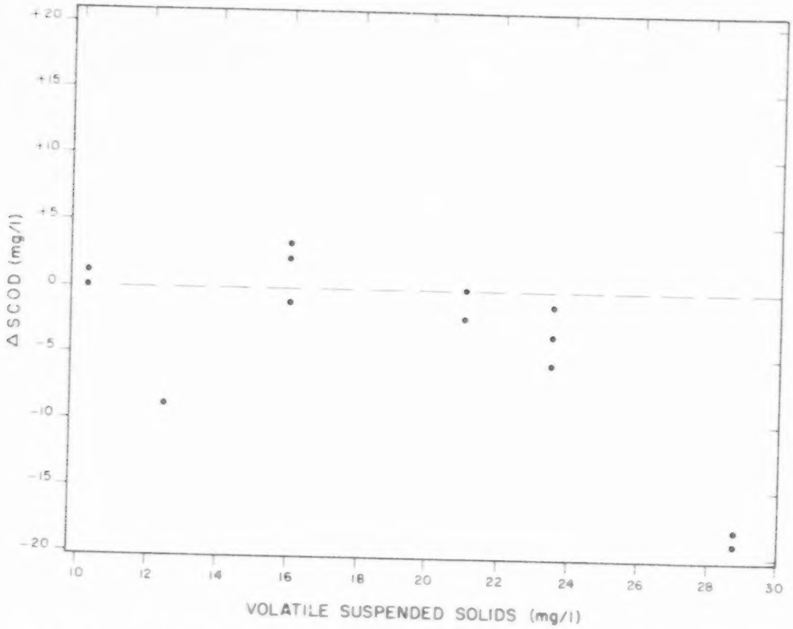

Figure C-3. Effects of 10-30 mg/l volatile suspended solids on observed changes in soluble COD between chlorinated and unchlorinated filtered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

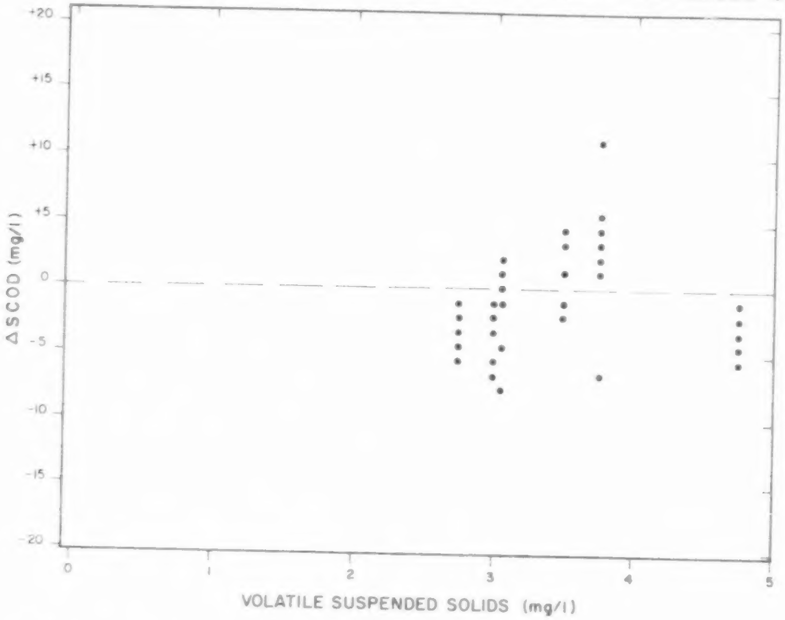

Figure C-4. Effects of 0-5 mg/l volatile suspended solids on observed changes in soluble COD between chlorinated and unchlorinated unfiltered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

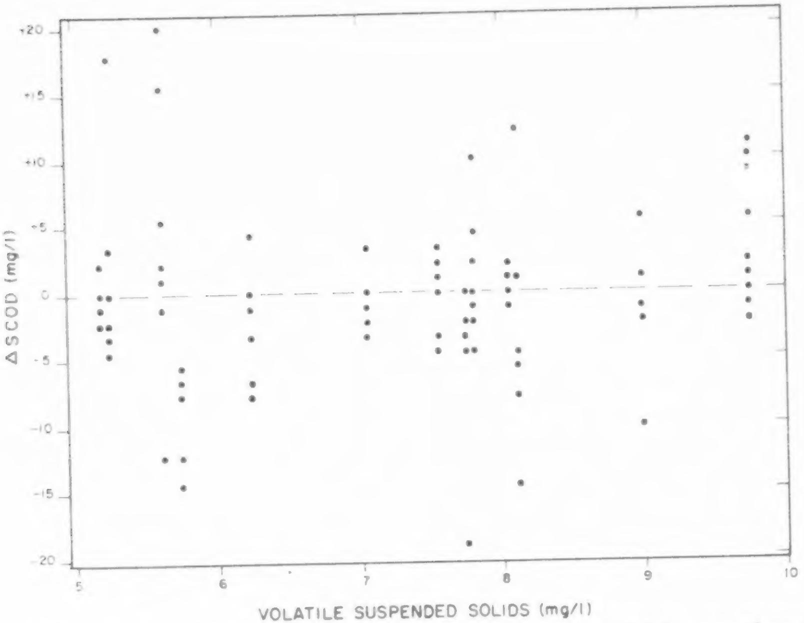

Figure C-5. Effects of 5-10 mg/l volatile suspended solids on observed changes in soluble COD between chlorinated and unchlorinated unfiltered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

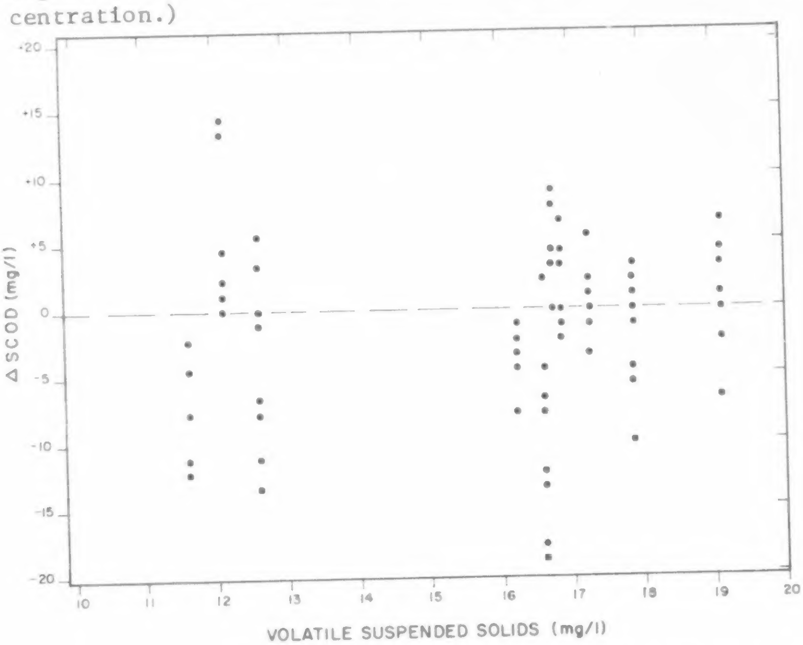

Figure C-6. Effects of 10-20 mg/l volatile suspended solids on observed changes in soluble COD between chlorinated and unchlorinated unfiltered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

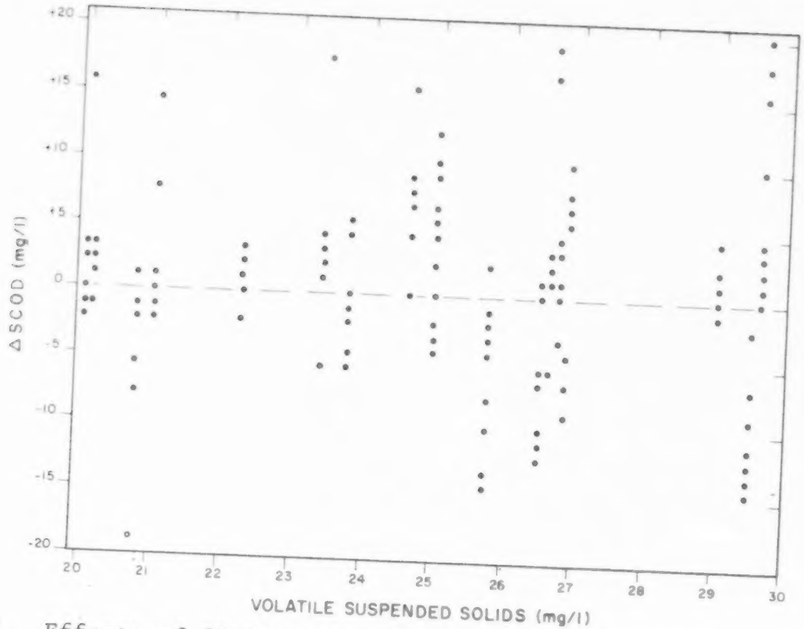

Figure C-7. Effects of 20-30 mg/l volatile suspended solids on observed changes in soluble COD between chlorinated an unchlorinated unfiltered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

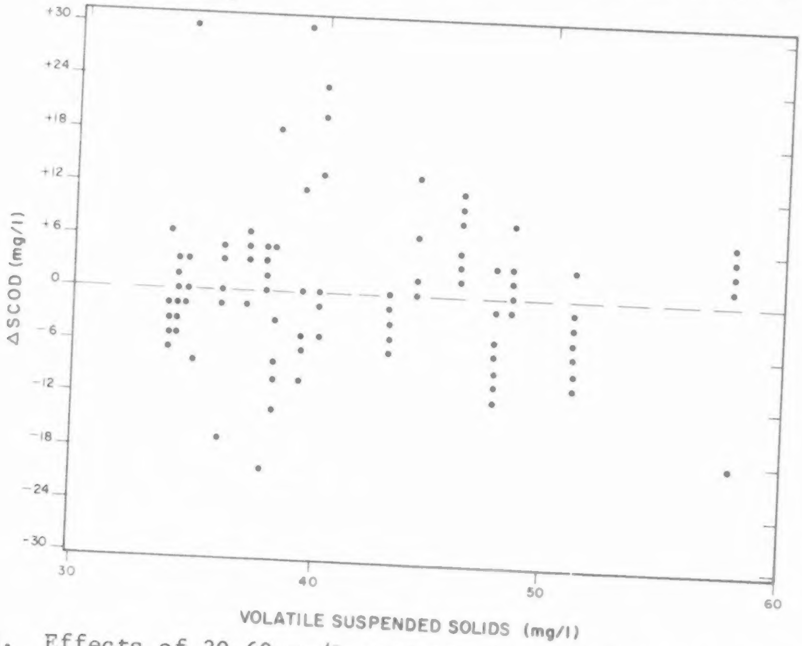

Figure C-8. Effects of 30-60 mg/l volatile suspended solids on observed changes in soluble COD between chlorinated and unchlorinated unfiltered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

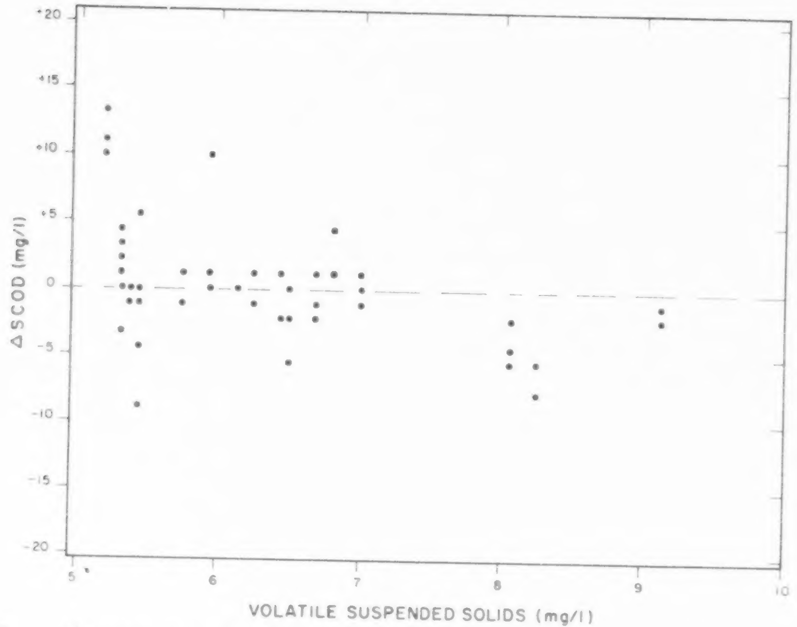

Figure C-9. Effects of 5-10 mg/l volatile suspended at chlorine dosages of 0-2 mg/l on observed changes in soluble COD between treated and untreated filtered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

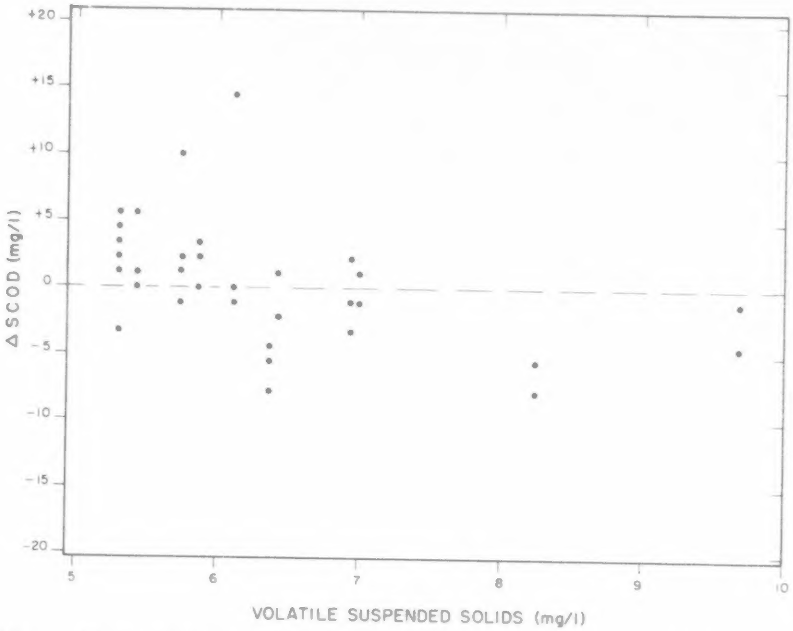

Figure C-10. Effects of 5-10 mg/l volatile suspended solids at chlorine dosages of >2 mg/l on observed changes in soluble COD between treated and untreated filtered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

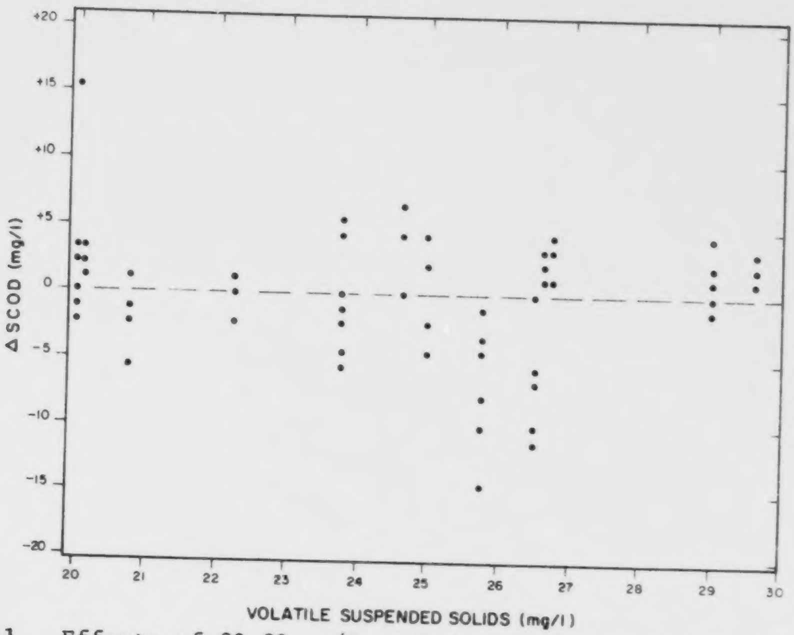

Figure C-11. Effects of 20-30 mg/l volatile suspended solids at chlorine dosages of 0-2 mg/l on observed changes in soluble COD between treated and untreated unfiltered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

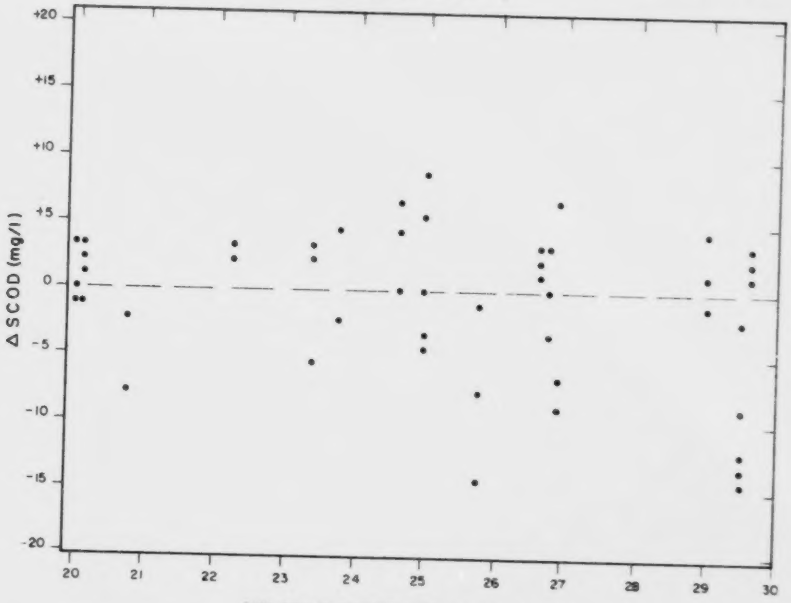

Figure C-12. Effects of 20-30 mg/l volatile suspended solids at chlorine dosages of 2-4 mg/l on observed changes in soluble COD between treated and untreated unfiltered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

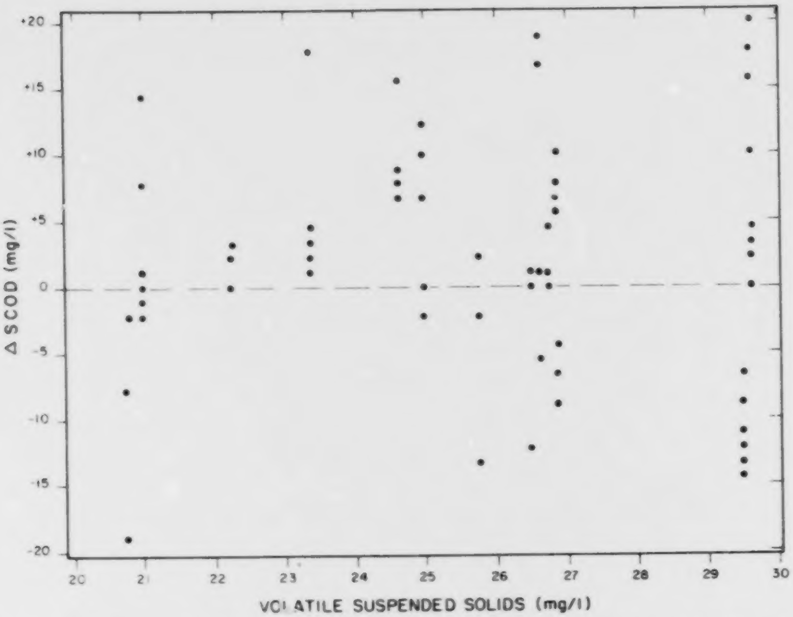

Figure C-13. Effects of 20-30 mg/l volatile suspended solids at chlorine dosages of >4 mg/l on observed changes in soluble COD between treated and untreated unfiltered lagoon effluent samples. (ΔSCOD = treated minus untreated concentration.)

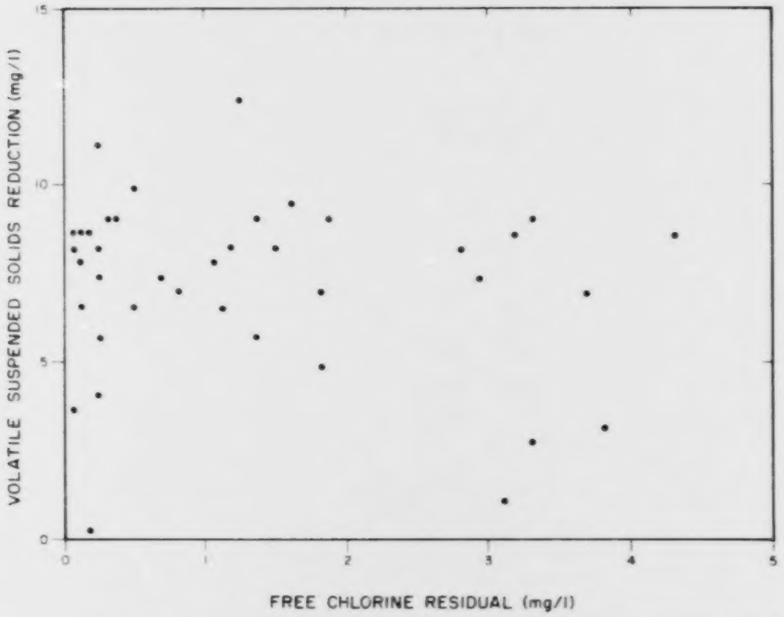

Figure C-14. Volatile suspended solids reduction from untreated to treated unfiltered lagoon effluent samples with respect to free chlorine residual.

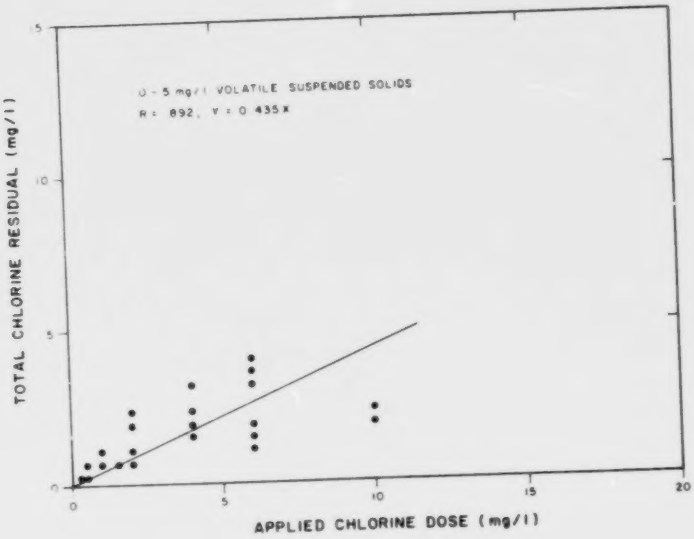

Figure C-15. Total chlorine residual after application of chlorine dosage using filtered lagoon effluent at 0-5 mg/l volatile suspended solids concentration.

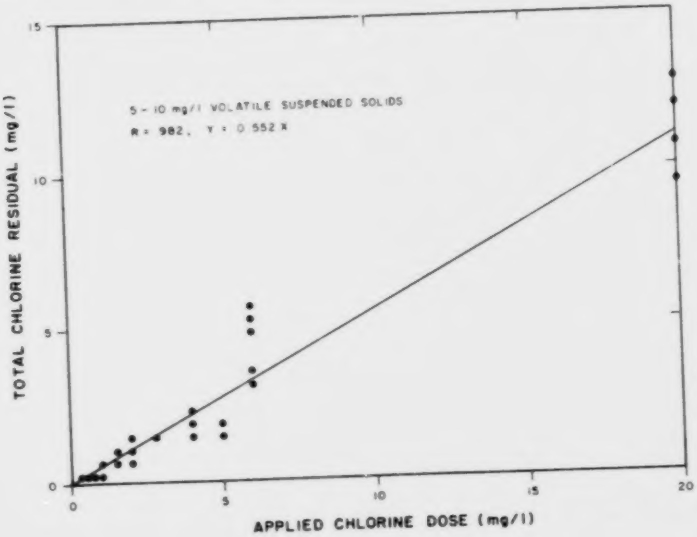

Figure C-16. Total chlorine residual remaining after application of chlorine dosage using filtered lagoon effluent at 5-10 mg/l volatile suspended solids concentration.

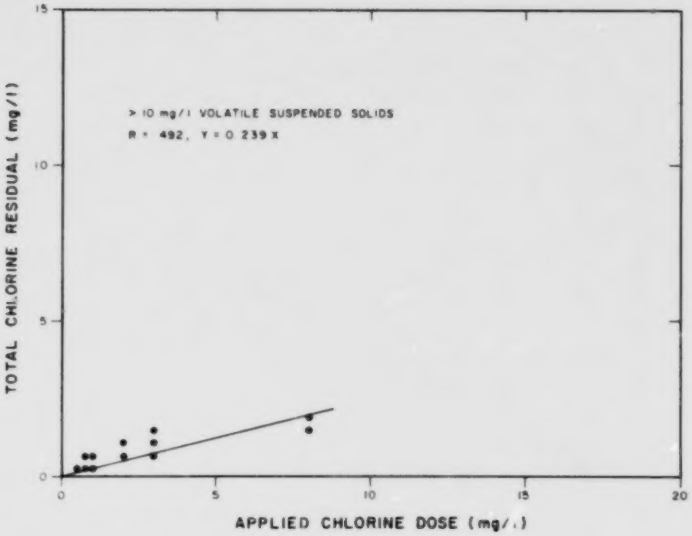

Figure C-17. Total chlorine residual remaining after application of chlorine dosage using filtered lagoon effluent at >10 mg/l volatile suspended solids concentration.

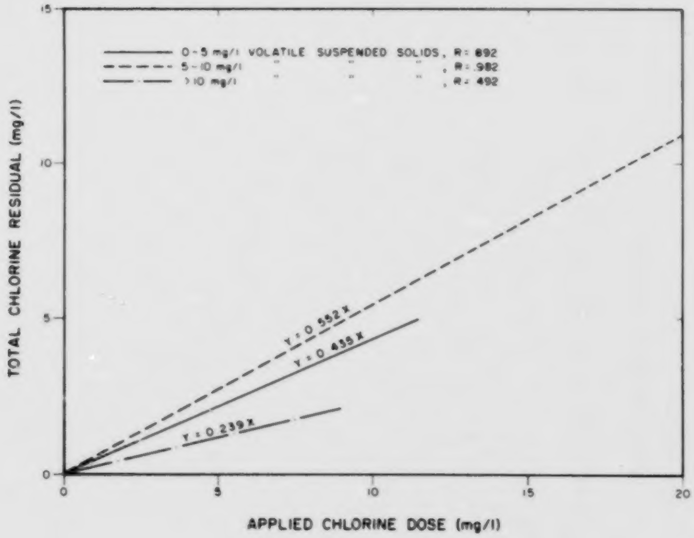

Figure C-18. Summary of volatile suspended solids concentration effects on the relationship between total chlorine residual and applied chlorine dosage using filtered lagoon effluents.

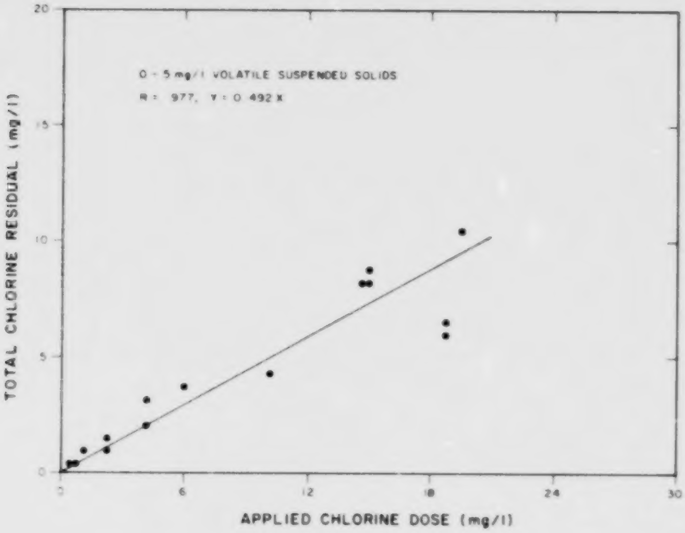

Figure C-19. Total chlorine residual remaining after application of chlorine dosage using unfiltered lagoon effluent at 0-5 mg/l volatile suspended solids concentration.

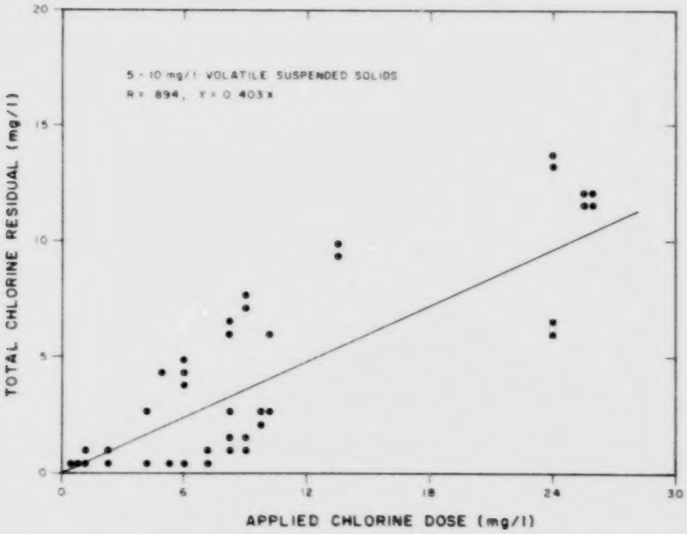

Figure C-20. Total chlorine residual remaining after application of chlorine dosage using unfiltered lagoon effluent at 5-10 mg/l volatile suspended solids concentration.

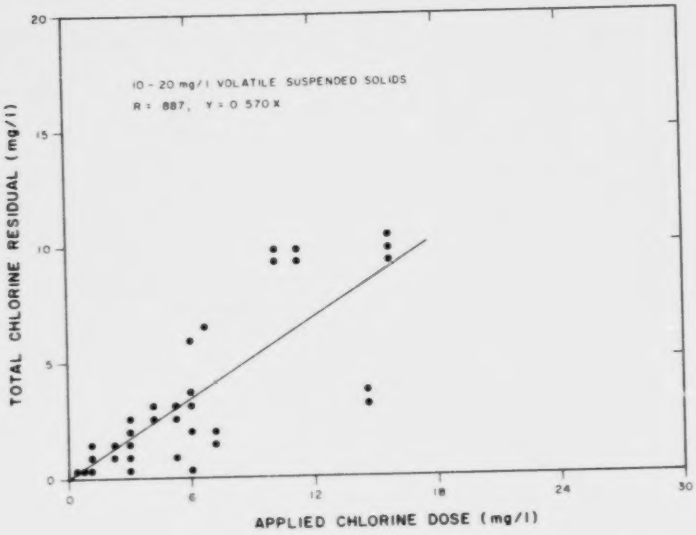

Figure C-21. Total chlorine residual remaining after application of chlorine dosage using unfiltered lagoon effluent at 10-20 mg/l volatile suspended solids concentration.

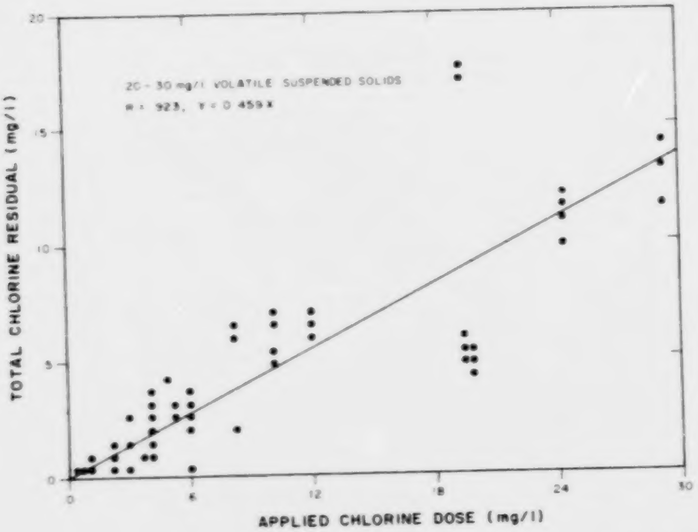

Figure C-22. Total chlorine residual remaining after application of chlorine dosage using unfiltered lagoon effluent at 20-30 mg/l volatile suspended solids concentration.

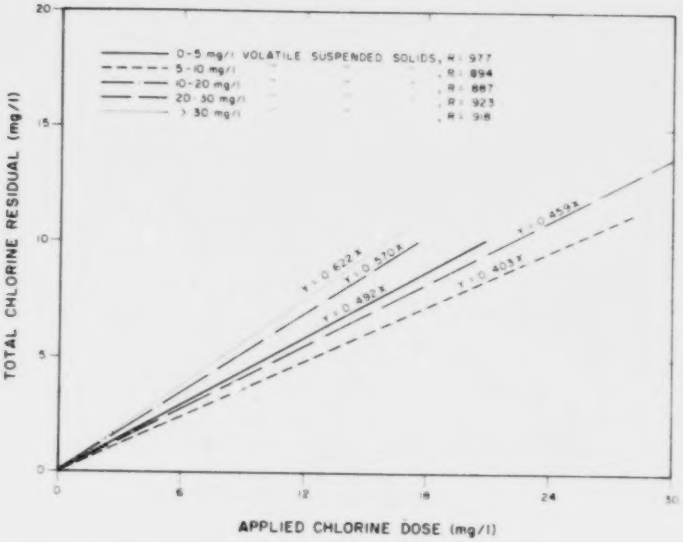

Figure C-23. Total chlorine residual remaining after application of chlorine dosage using unfiltered lagoon effluent at >30 mg/l volatile suspended solids concentration.

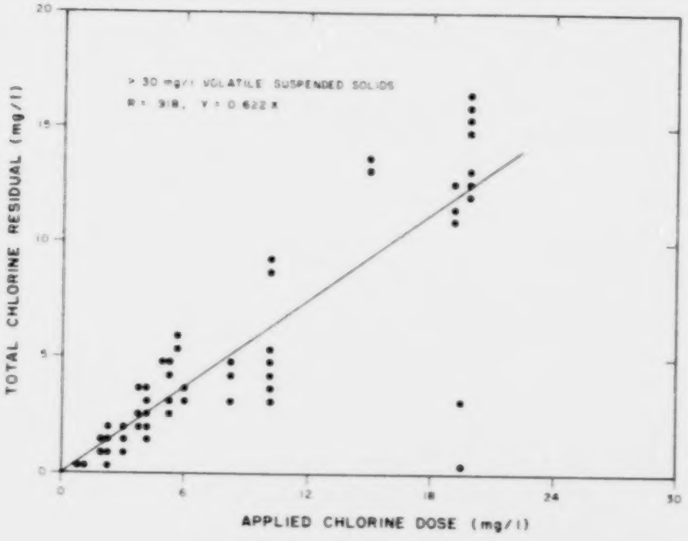

Figure C-24. Summary of volatile suspended solids concentration effects on the relationship between total chlorine residual and applied chlorine dosage using unfiltered lagoon effluent.

APPENDIX D
COLIFORM REDUCTION DATA

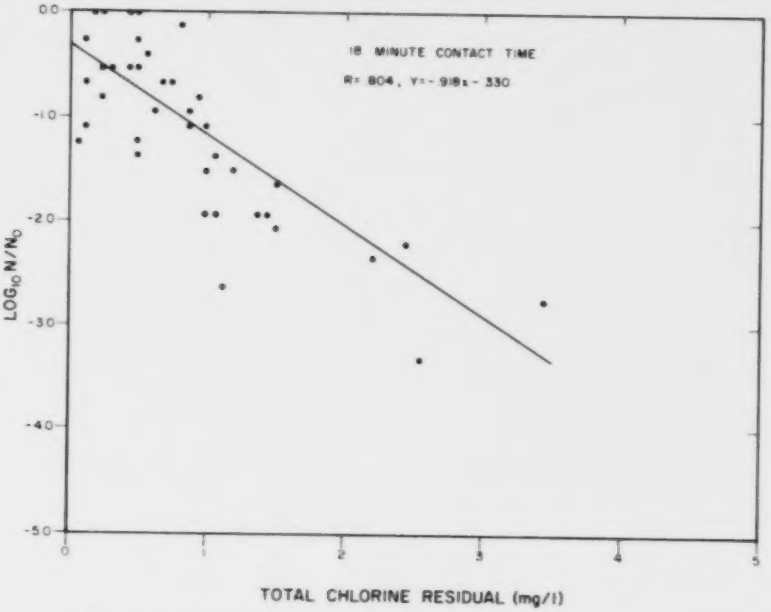

Figure D-1. Total coliform removal efficiency, using filtered lagoon effluent, as a function of total chlorine residual at 18 minutes of chlorine contact without a forced zero intercept.

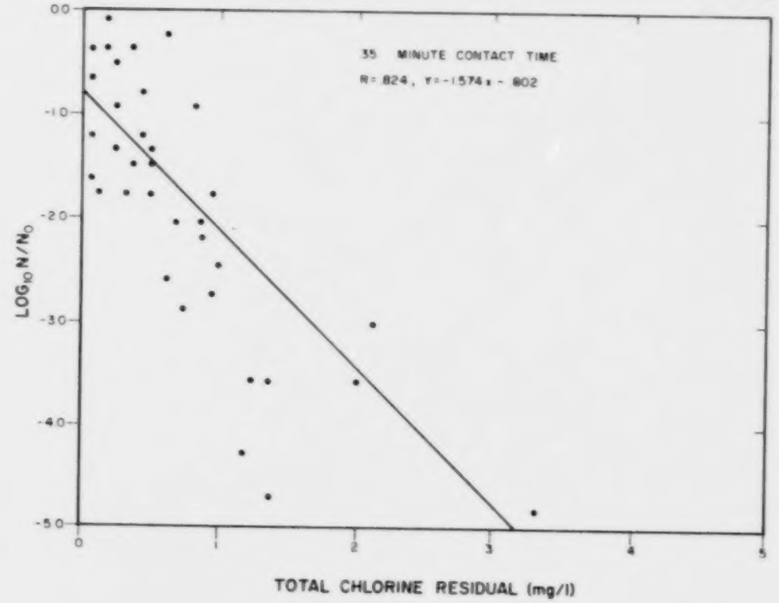

Figure D-2. Total coliform removal efficiency, using filtered lagoon effluent, as a function of total chlorine residual at 35 minutes of chlorine contact without a forced zero intercept.

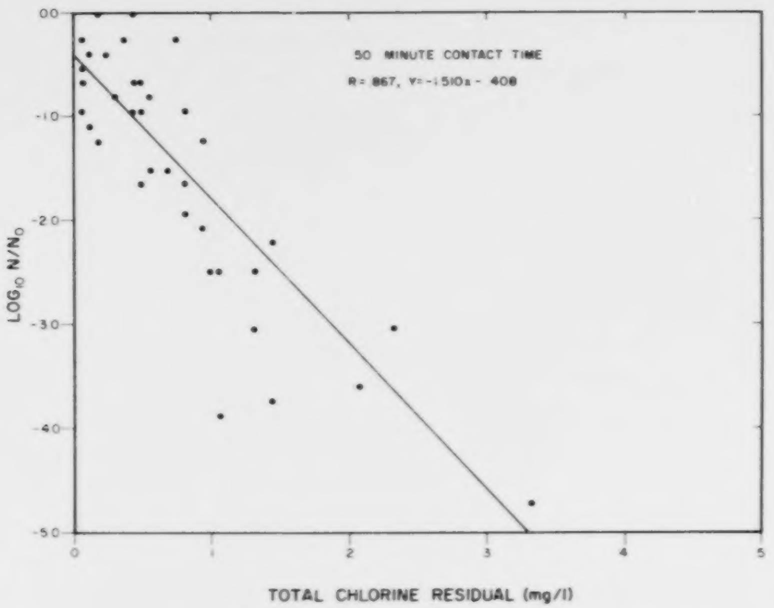

Figure D-3. Total coliform removal efficiency, using filtered lagoon effluent, as a function of total chlorine residual at 50 minutes of chlorine contact without a forced zero intercept.

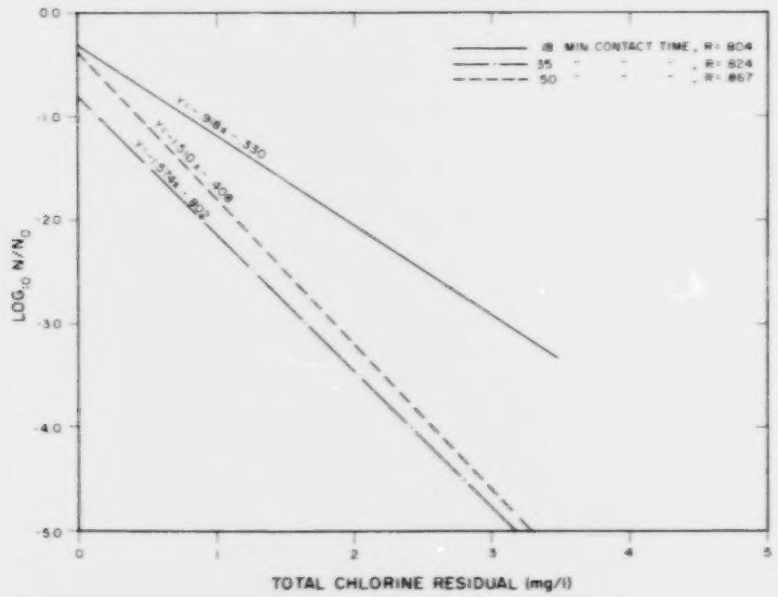

Figure D-4. Summary of total coliform removal efficiency, using filtered lagoon effluent, as a function of total chlorine residual at various chlorine contact times without forced zero intercepts.

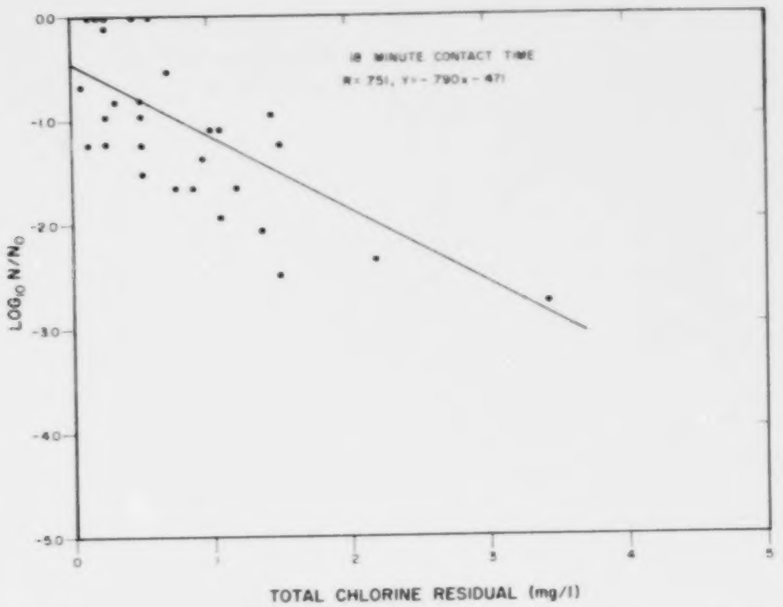

Figure D-5. Fecal coliform removal efficiency, using filtered lagoon effluent, as a function of total chlorine residual at 18 minutes of chlorine contact without a forced zero intercept.

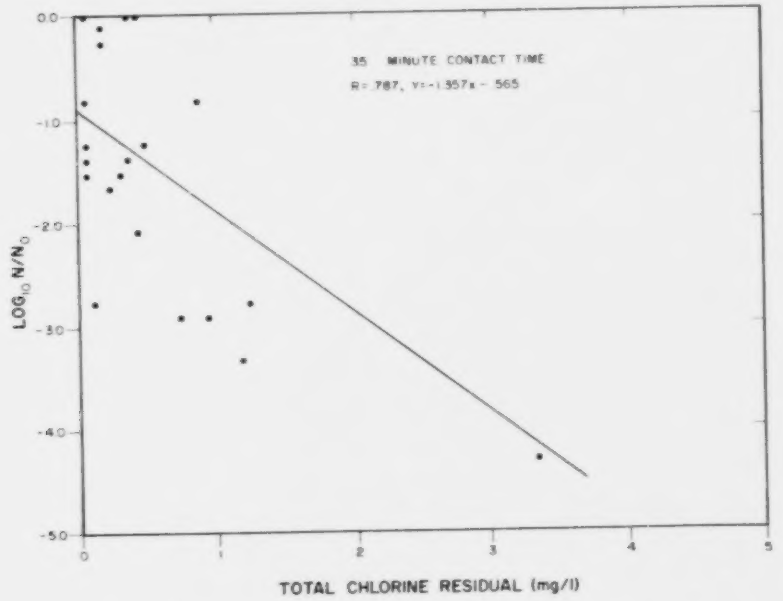

Figure D-6. Fecal coliform removal efficiency, using filtered lagoon effluent, as a function of total chlorine residual at 35 minutes of chlorine contact without a forced zero intercept.

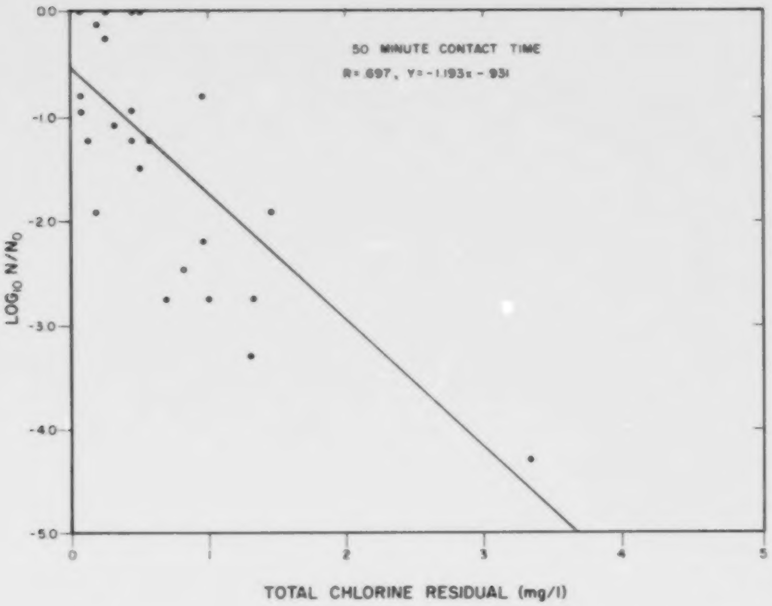

Figure D-7. Fecal coliform removal efficiency, using filtered lagoon effluent, as a function of total chlorine residual at 50 minutes of chlorine contact without a forced zero intercept.

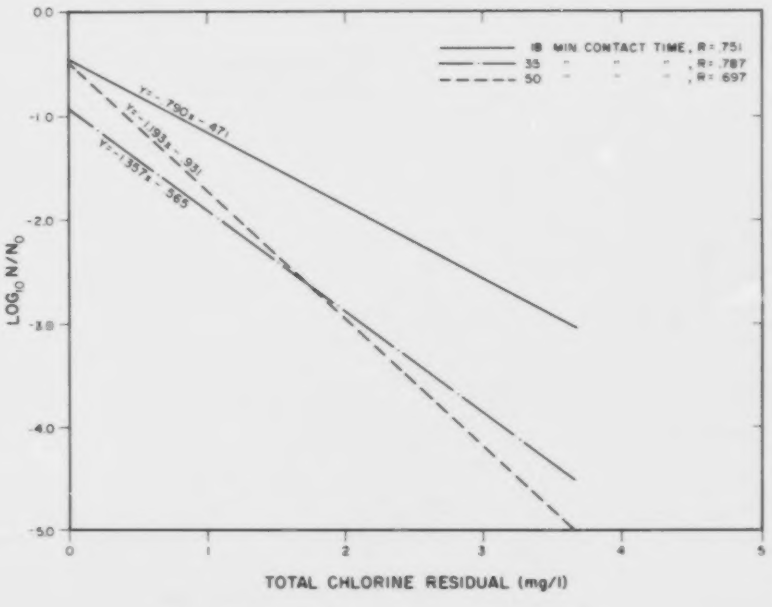

Figure D-8. Summary of fecal coliform removal efficiency, using filtered lagoon effluent, as a function of total chlorine residual at various chlorine contact times without forced zero intercepts.

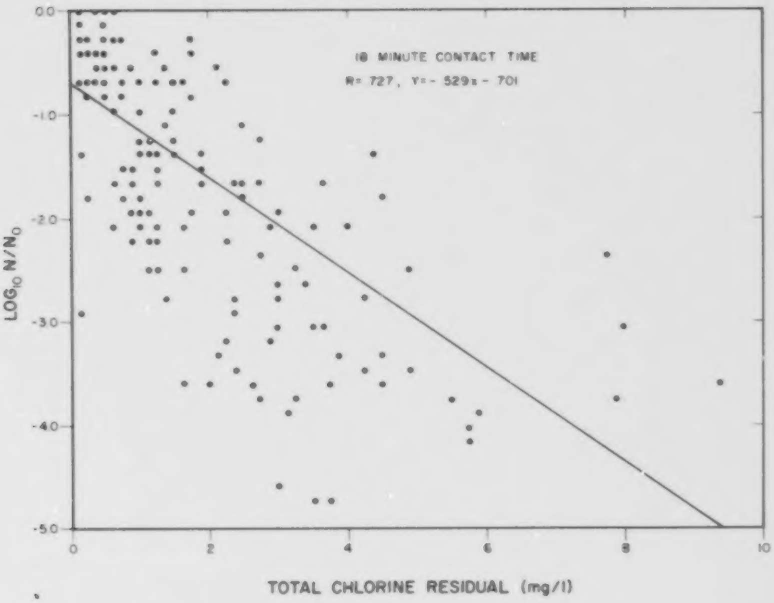

Figure D-9. Total coliform removal efficiency, using unfiltered lagoon effluent, as a function of total chlorine residual at 18 minutes of chlorine contact without a forced zero intercept.

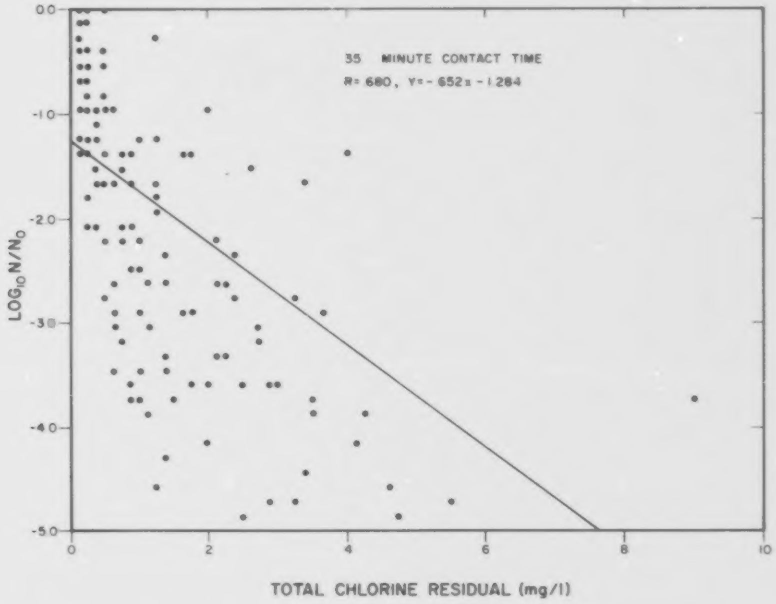

Figure D-10. Total coliform removal efficiency, using unfiltered lagoon effluent, as a function of total chlorine residual at 35 minutes of chlorine contact without a forced zero intercept.

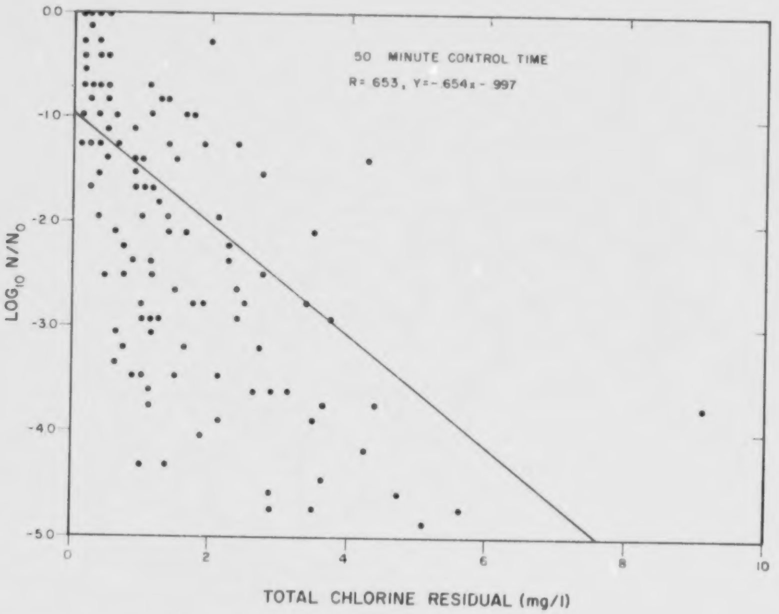

Figure D-11. Total coliform removal efficiency, using unfiltered lagoon effluent, as a function of total chlorine residual at 50 minutes of chlorine contact without a forced zero intercept.

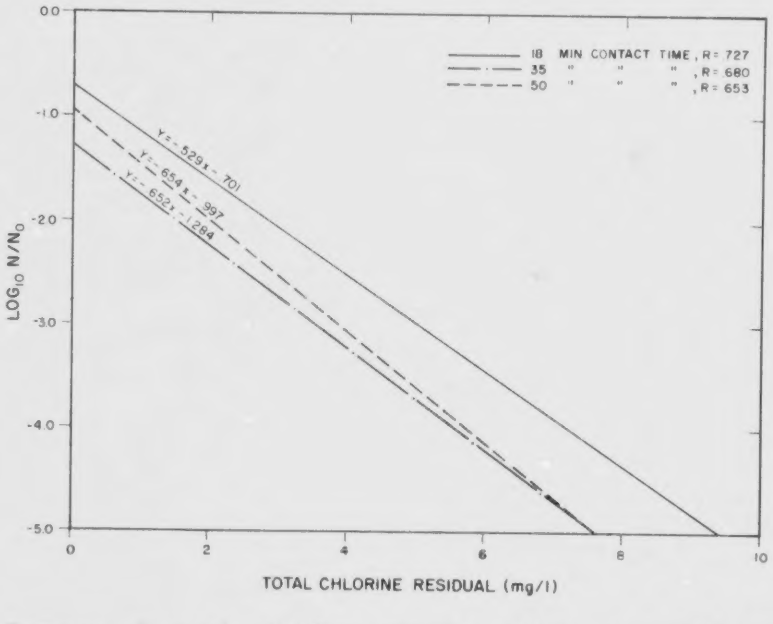

Figure D-12. Summary of total coliform removal efficiency, using unfiltered lagoon effluent, as a function of total chlorine residual at various chlorine contact times without forced zero intercepts.

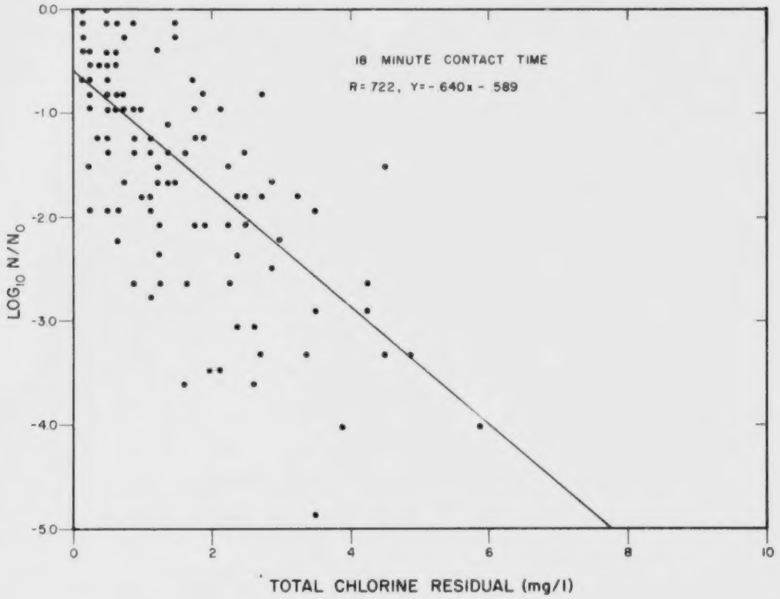

Figure D-13. Fecal coliform removal efficiency, using unfiltered lagoon effluent, as a function of total chlorine residual at 18 minutes of chlorine contact without a forced zero intercept.

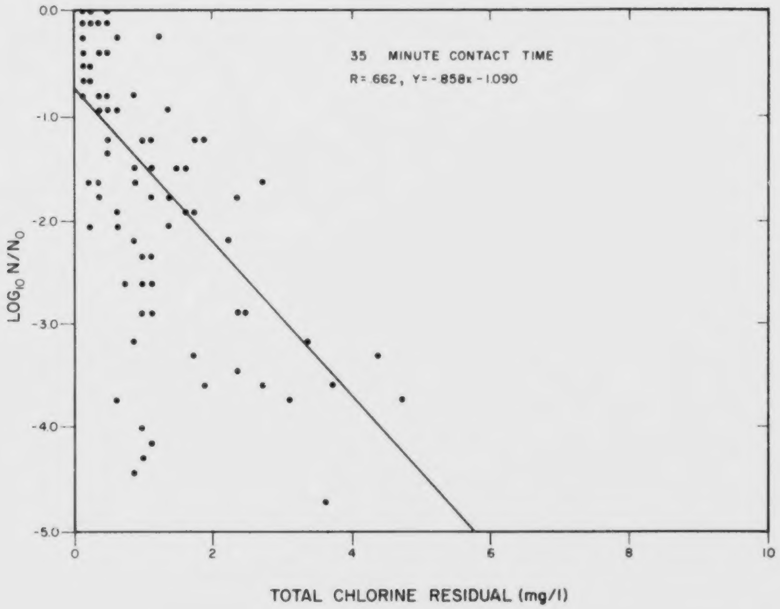

Figure D-14. Fecal coliform removal efficiency, using unfiltered lagoon effluent, as a function of total chlorine residual at 35 minutes of chlorine contact without a forced zero intercept.

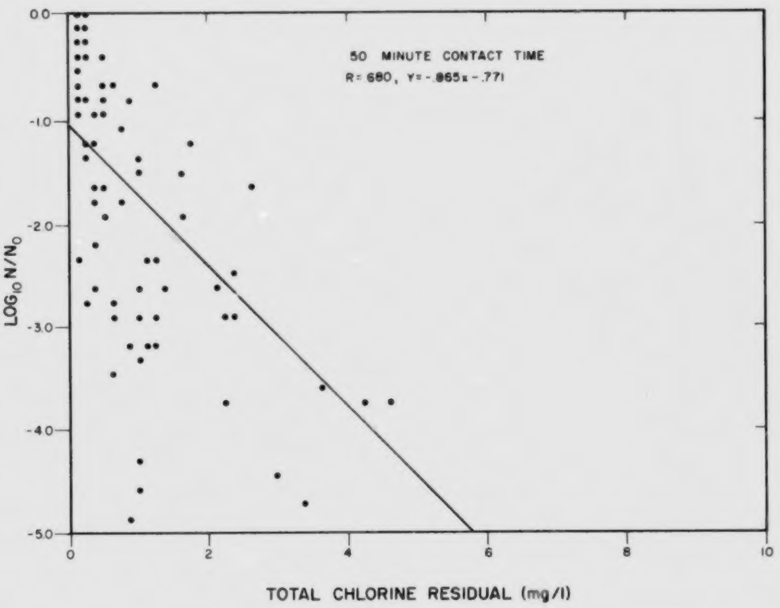

Figure D-15. Fecal coliform removal efficiency, using unfiltered lagoon effluent, as a function of total chlorine residual at 50 minutes of chlorine contact without a forced zero intercept.

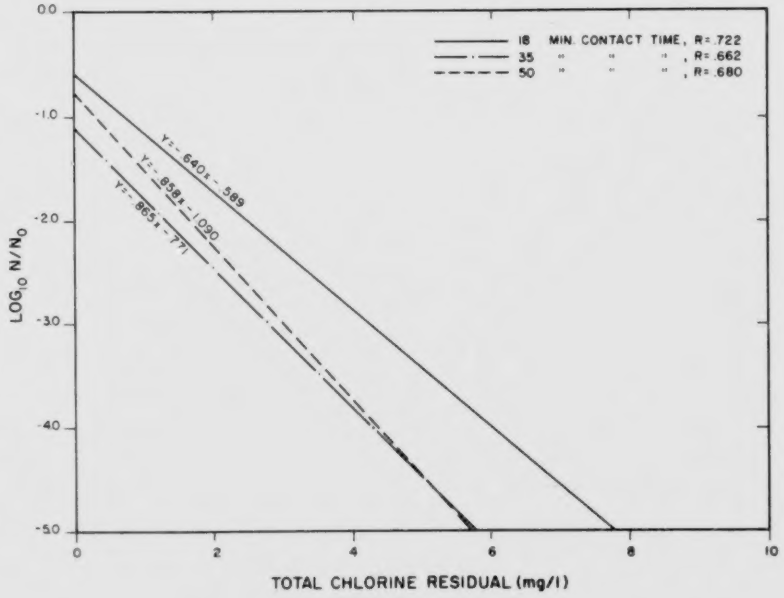

Figure D-16. Summary of fecal coliform removal efficiency, using unfiltered lagoon effluent, as a function of total chlorine residual at various chlorine contact times without forced zero intercepts.

APPENDIX E

LAGOON EVALUATION DATA
JUNE 1, 1975 - AUGUST 24, 1976

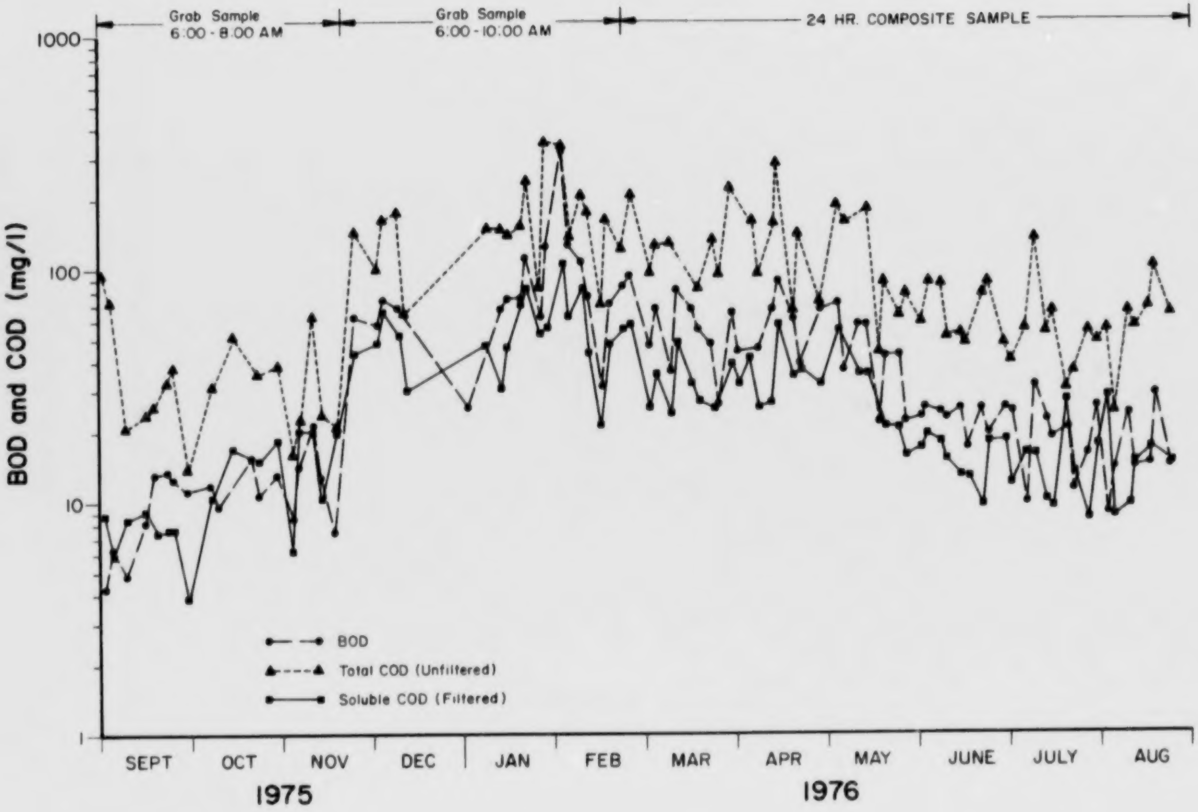

Figure E-1. BOD and COD at sample station No. 1 (influent).

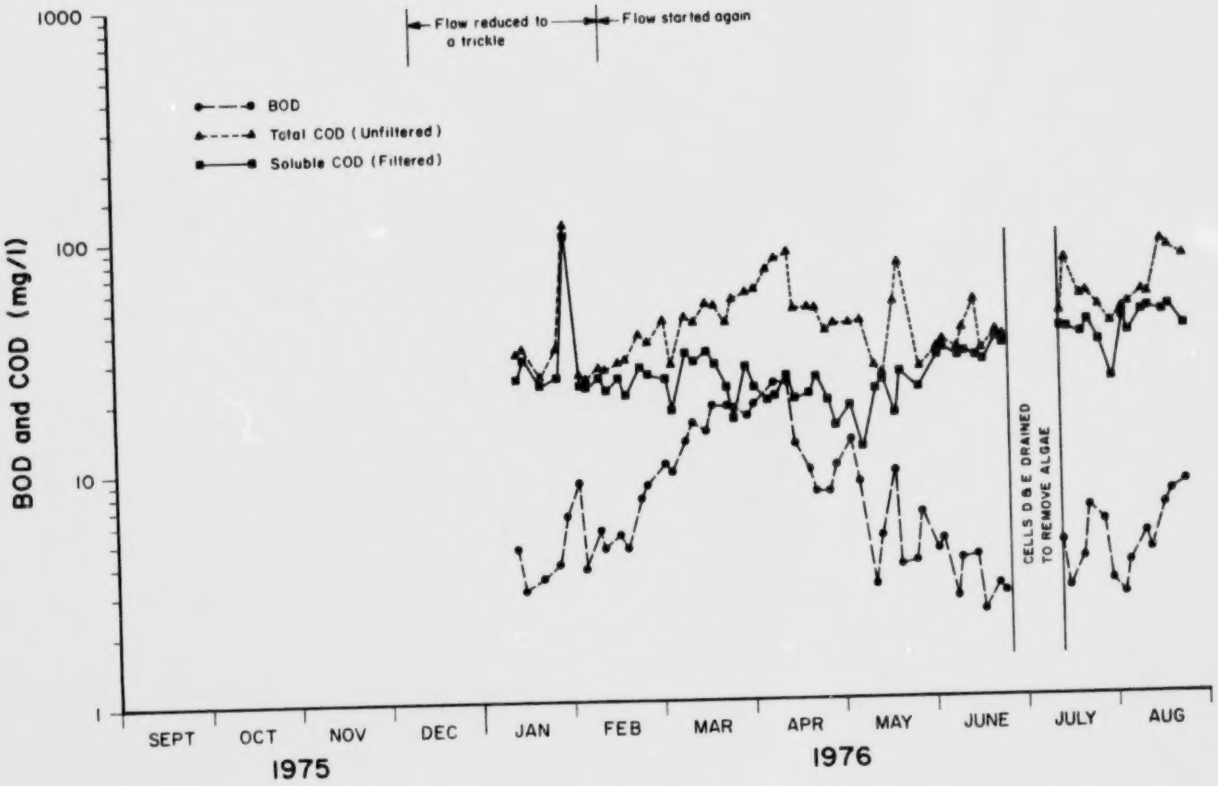

Figure E-2. BOD and COD at sample station No. 9 (final effluent).

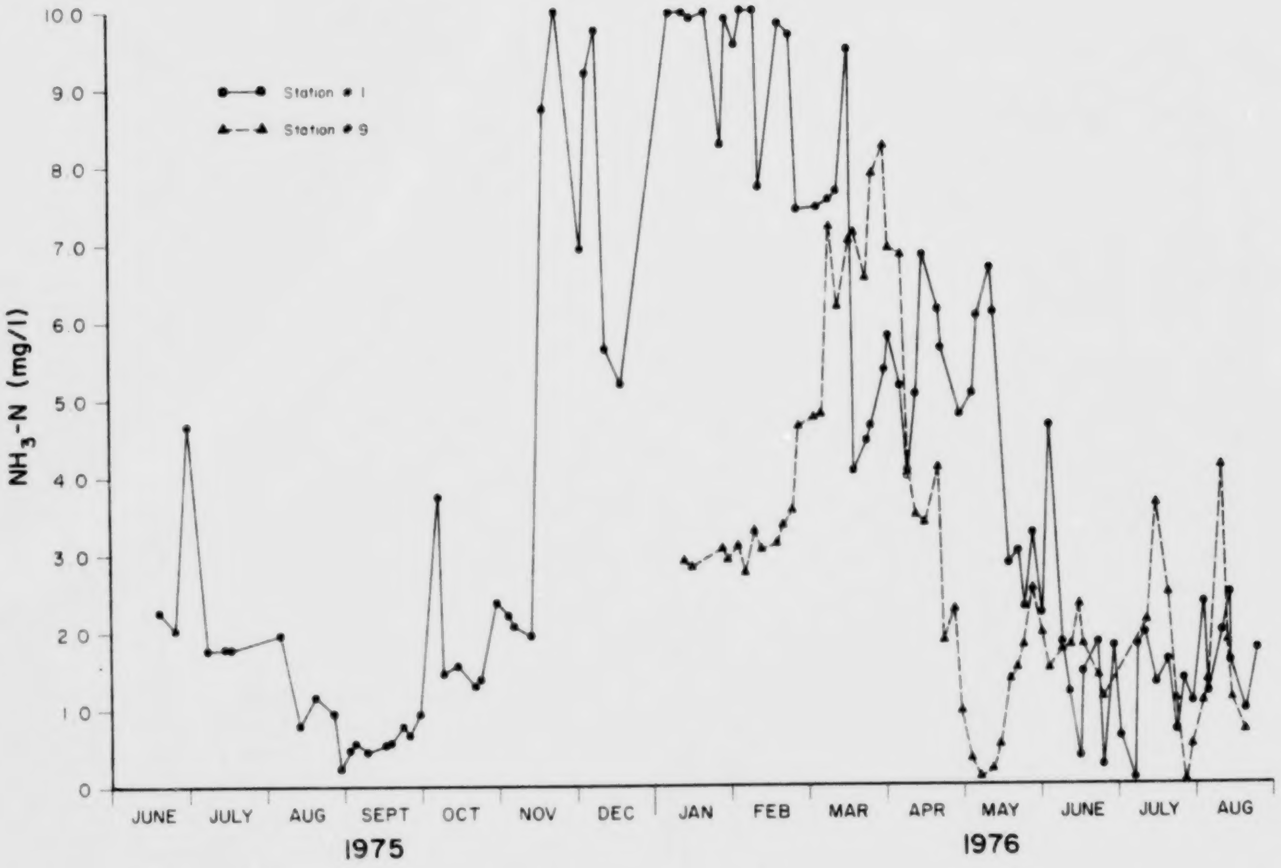

Figure E-3. NH_3-N, sample stations No. 1 and No. 9.

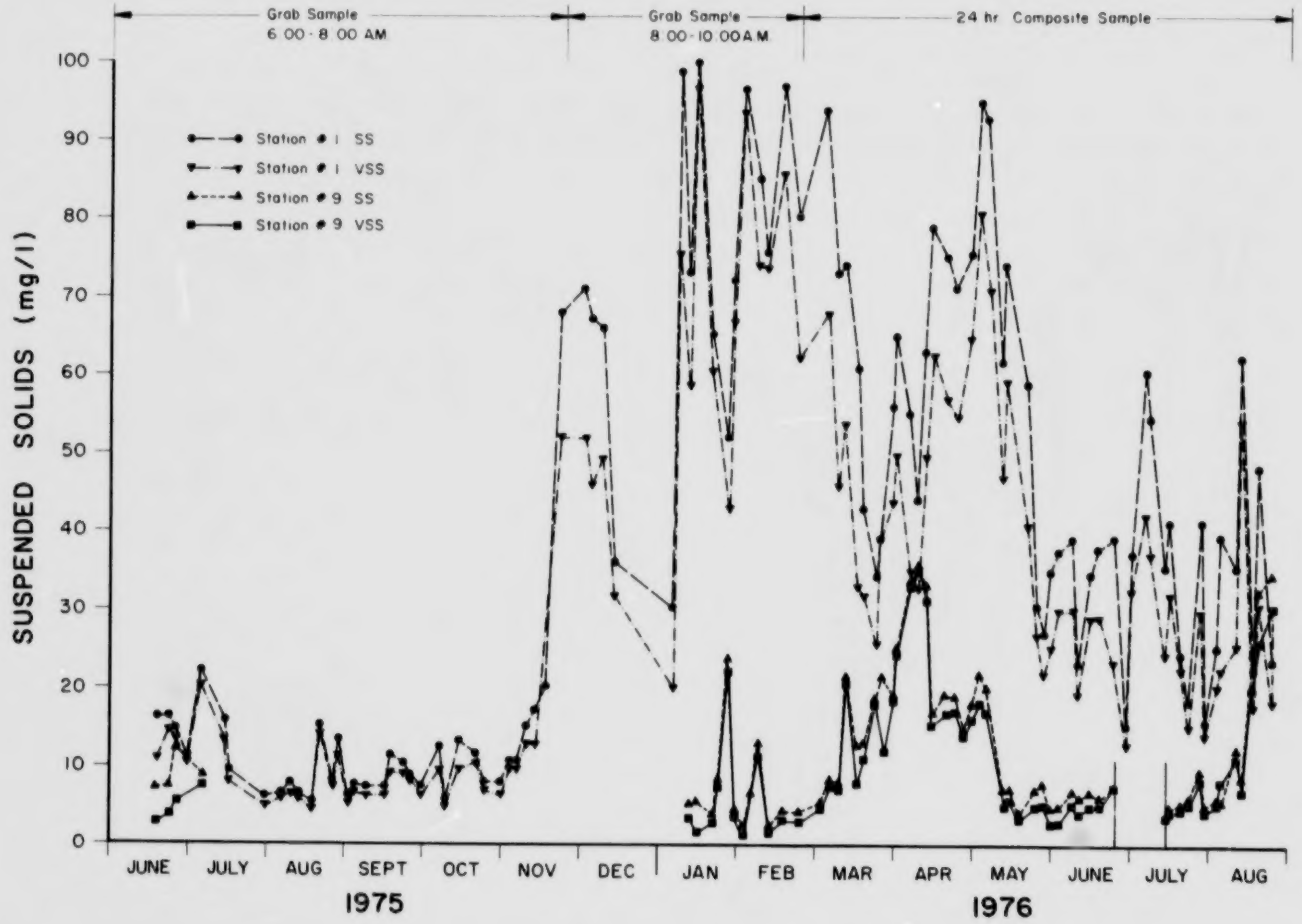

Figure E-4. SS and VSS sample stations No. 1 and No. 9.

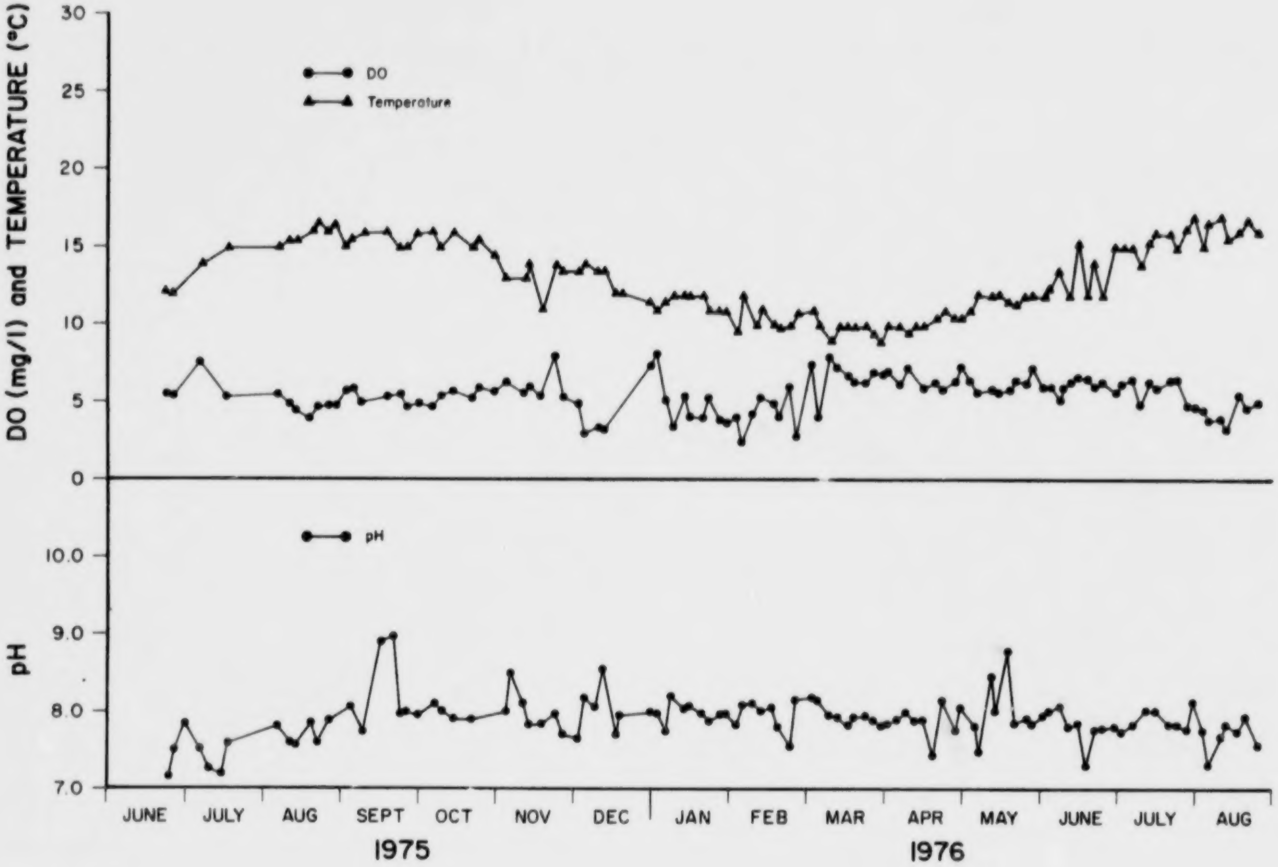

Figure E-5. Seasonal temperature, DO, and pH at sample station No. 1.

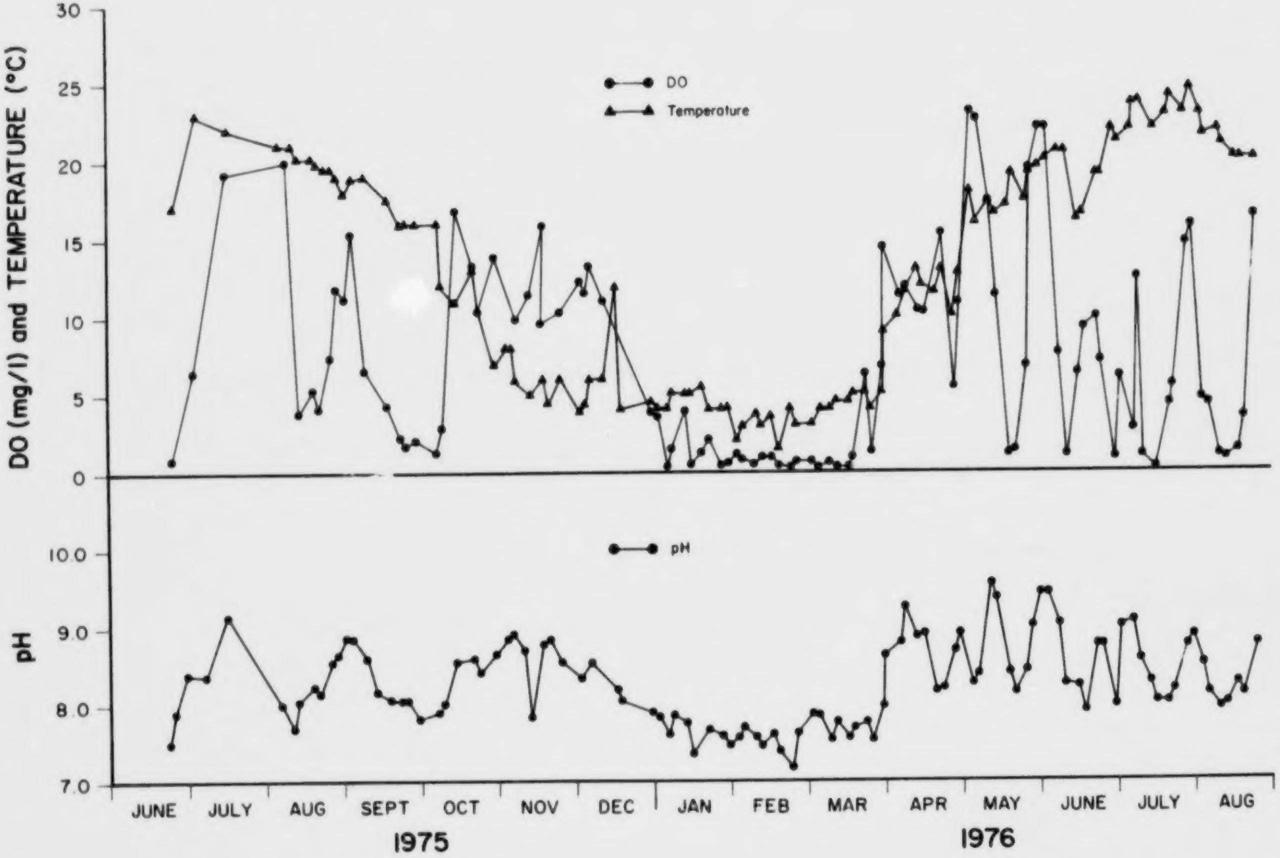

Figure E-6. Seasonal temperature, DO, and pH at sample station No. 2.

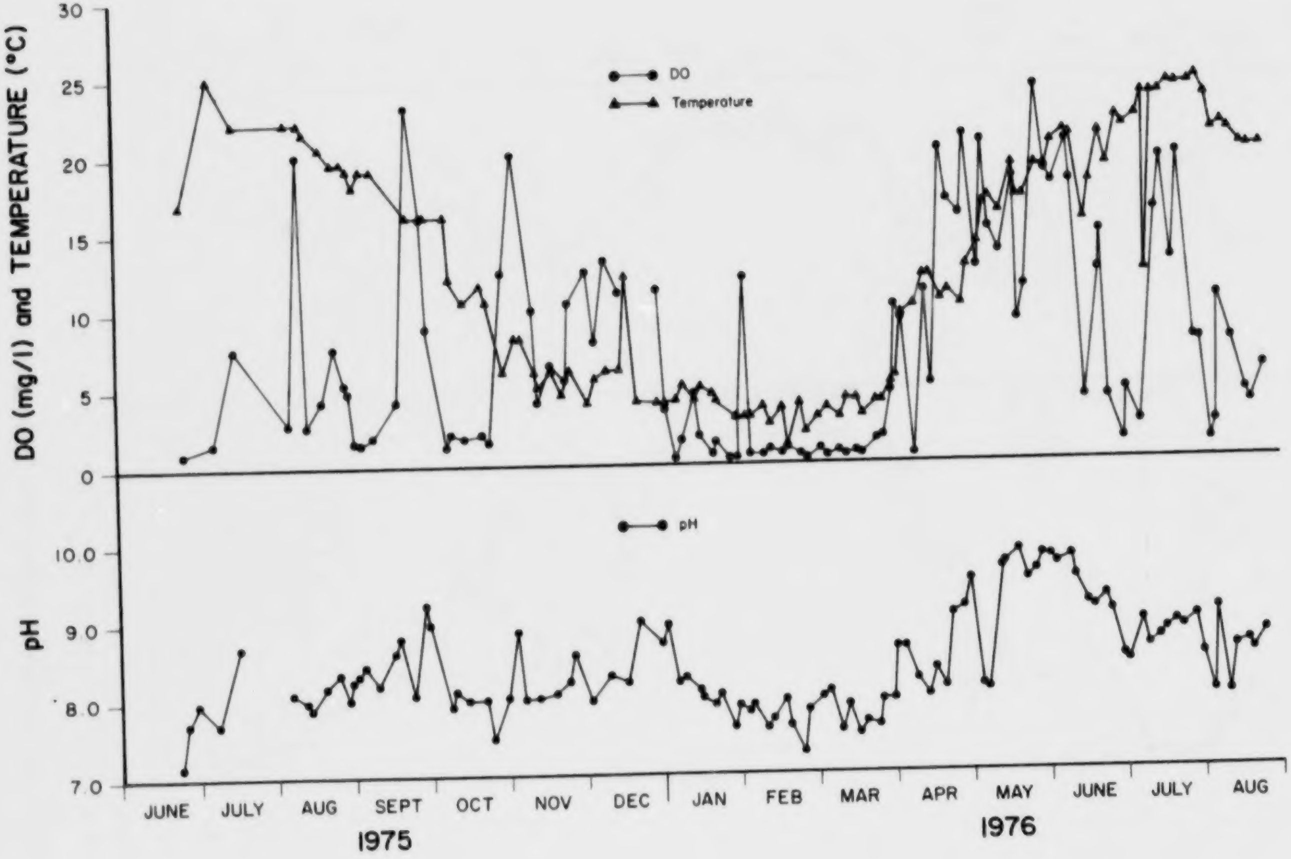

Figure E-7. Seasonal temperature, DO, and pH at sample station No. 3.

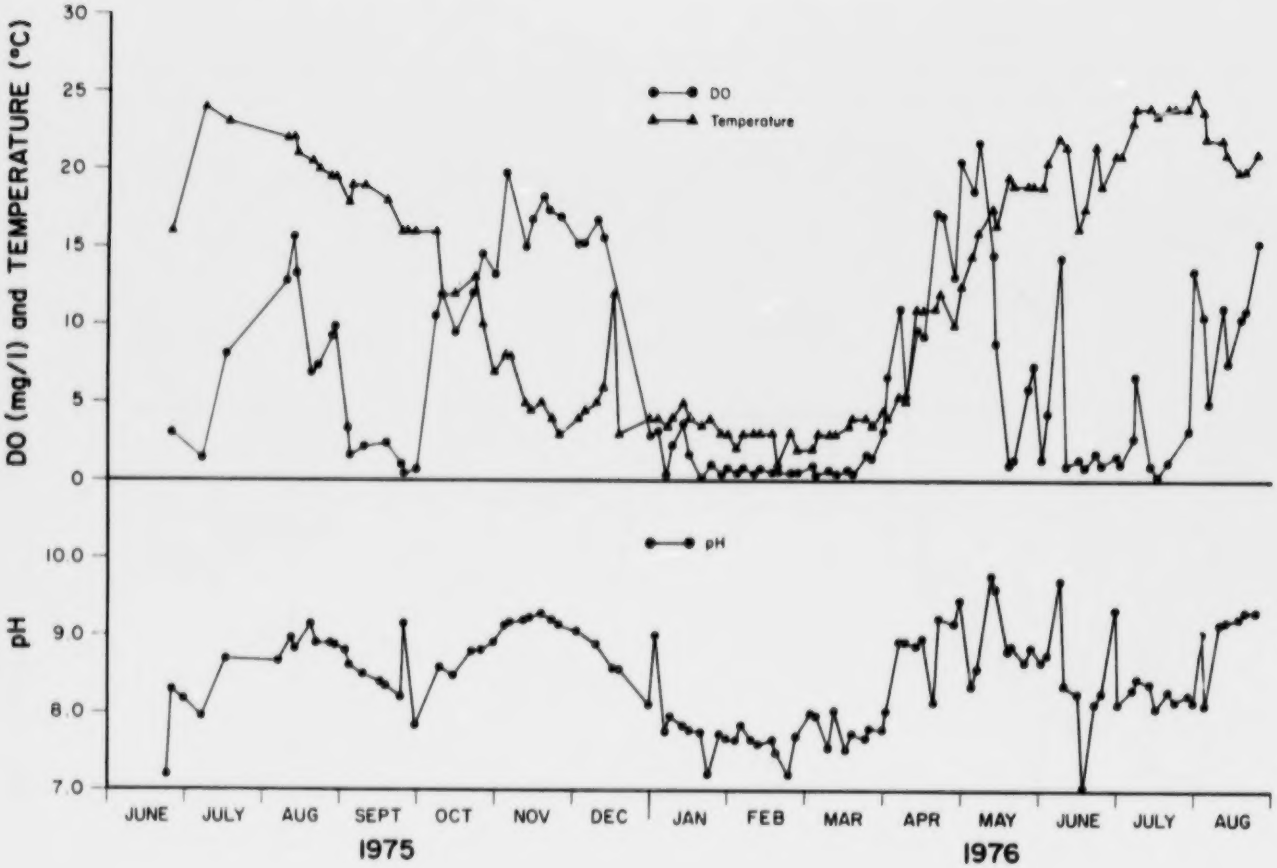

Figure E-8. Seasonal temperature, DO, and pH at sample station No. 4.

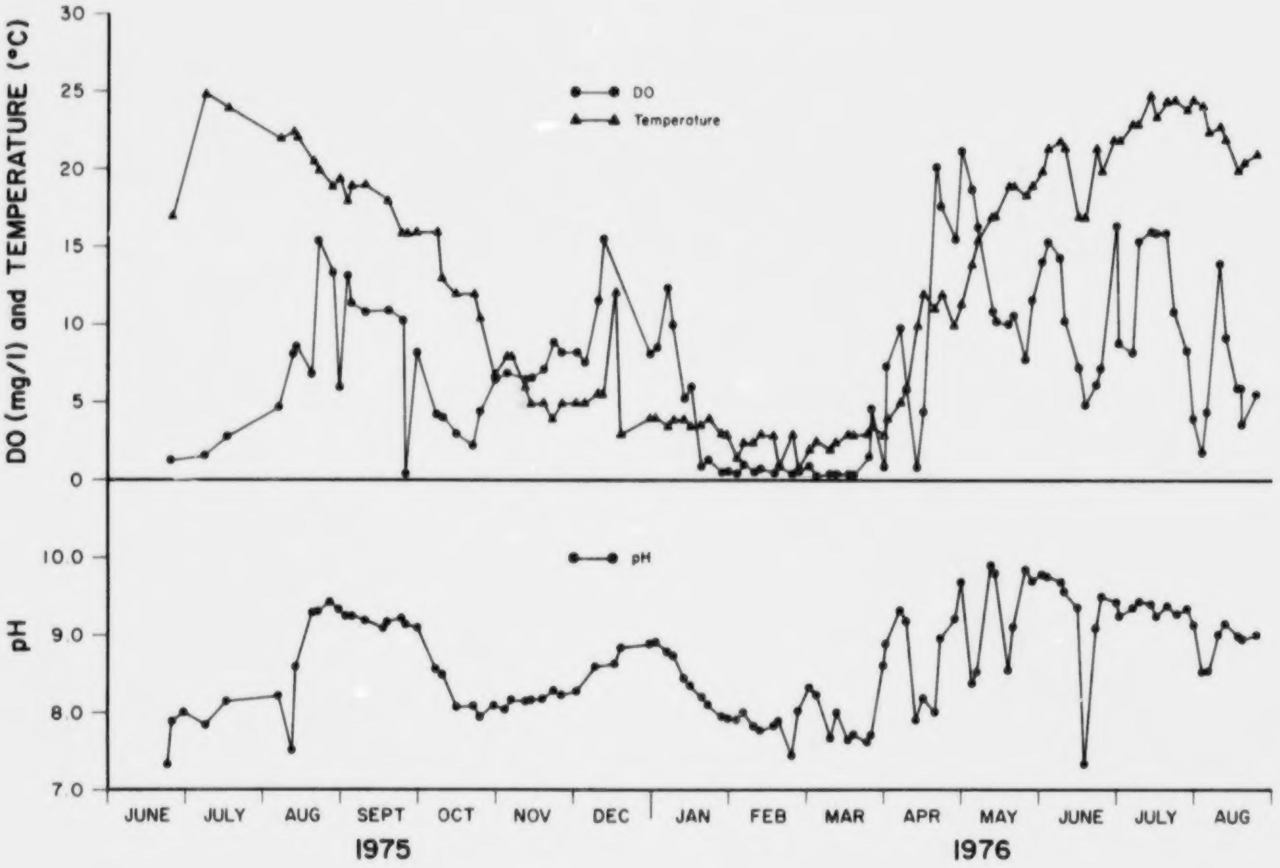

Figure E-9. Seasonal temperature, DO, and pH at sample station No. 5.

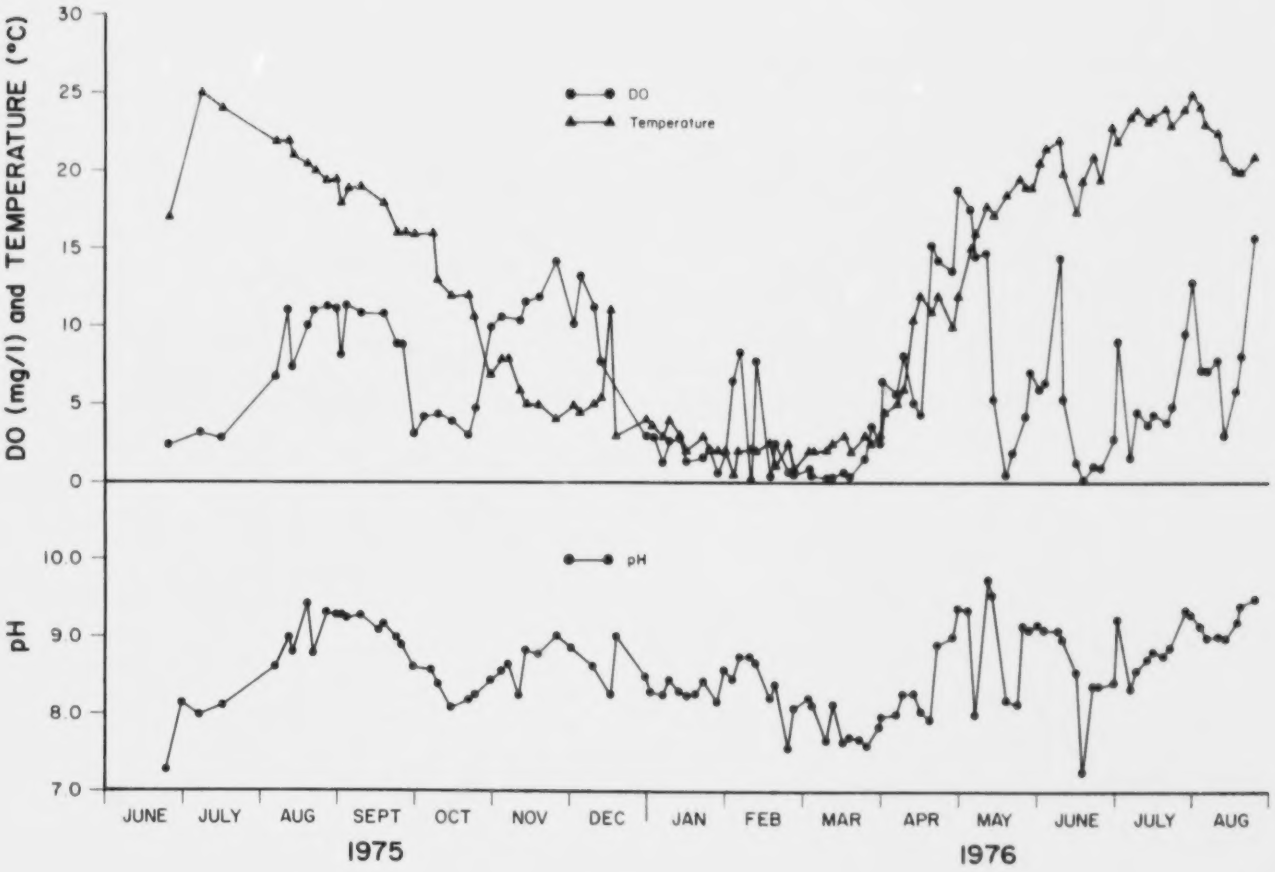

Figure E-10. Seasonal temperature, DO, and pH at sample station No. 6.

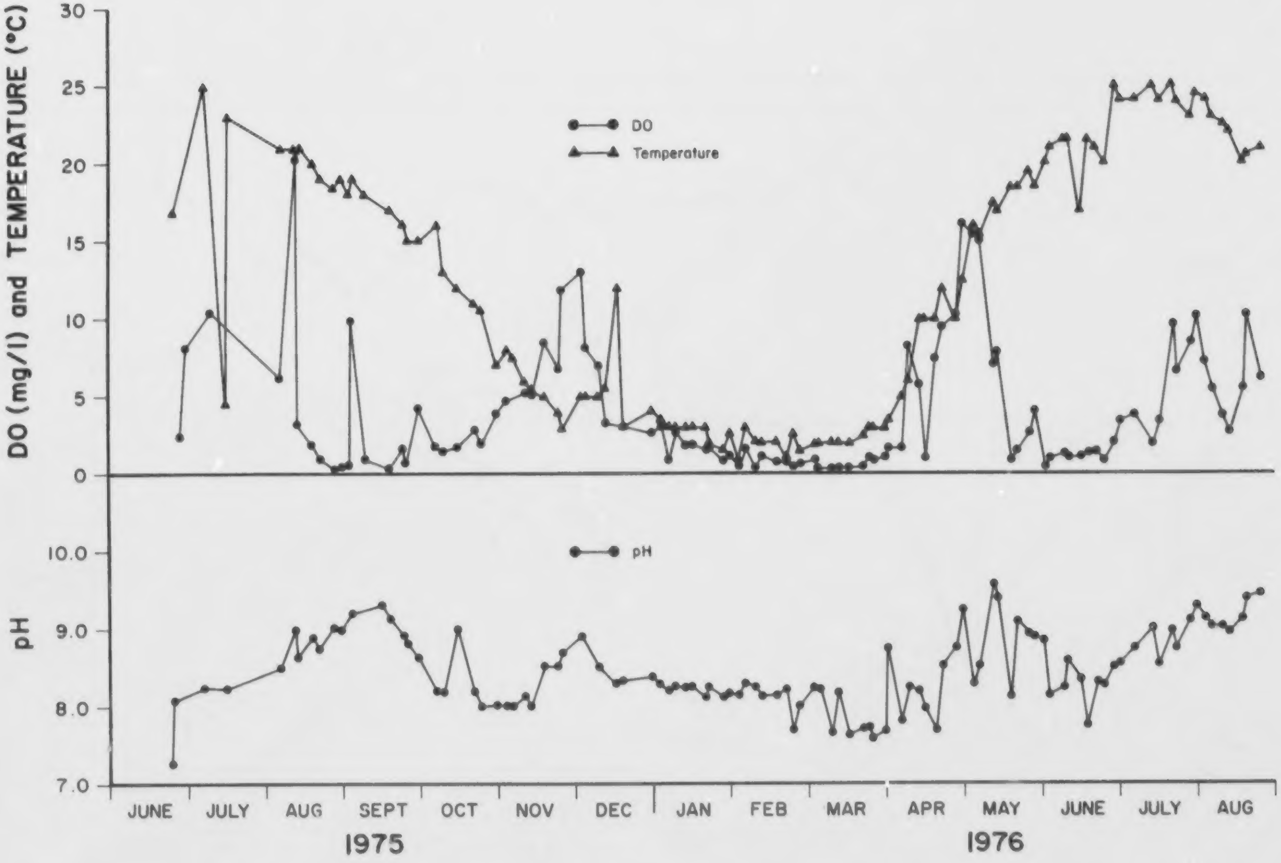

Figure E-11. Seasonal temperature, DO, and pH at sample station No. 7.

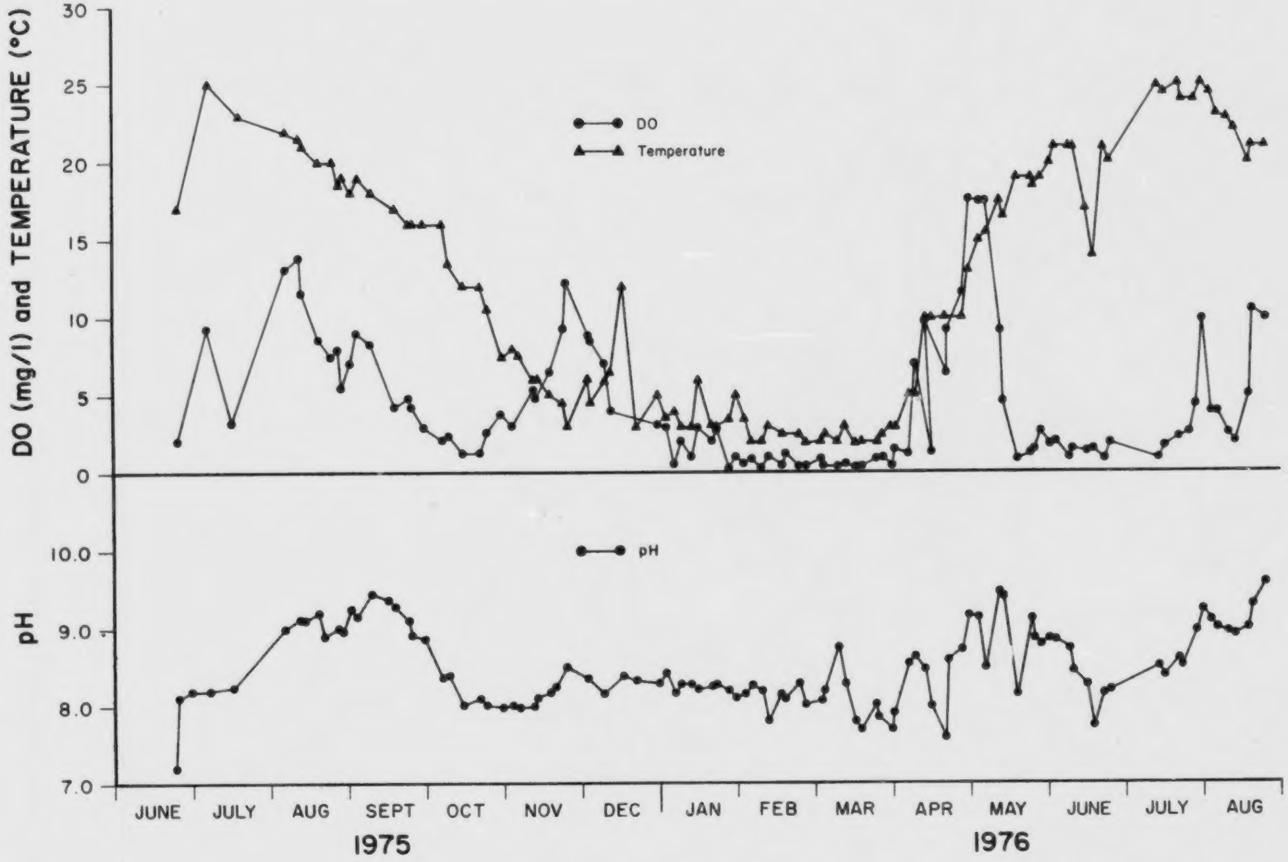

Figure E-12. Seasonal temperature, DO, and pH at sample station No. 8.

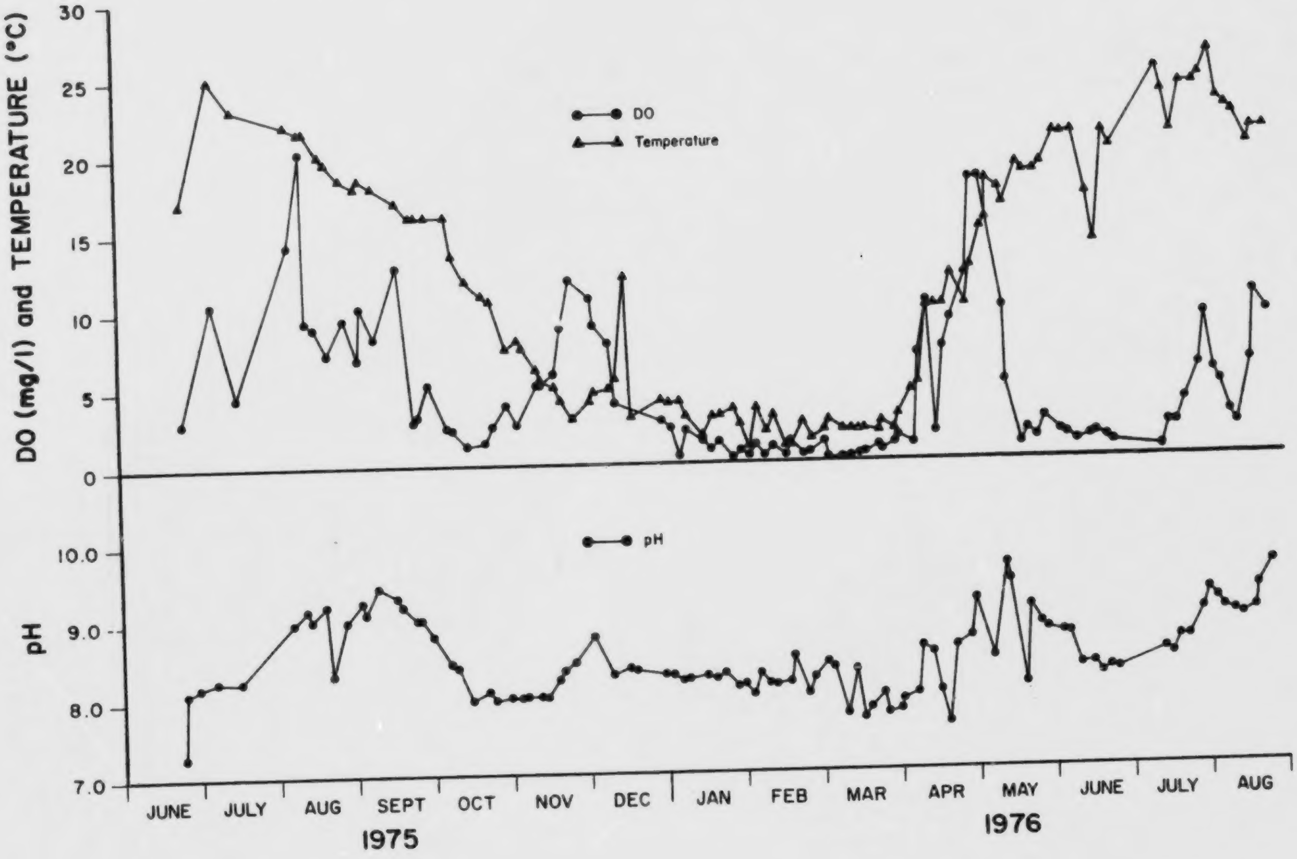

Figure E-13. Seasonal temperature, DO, and pH at sample station No. 9.

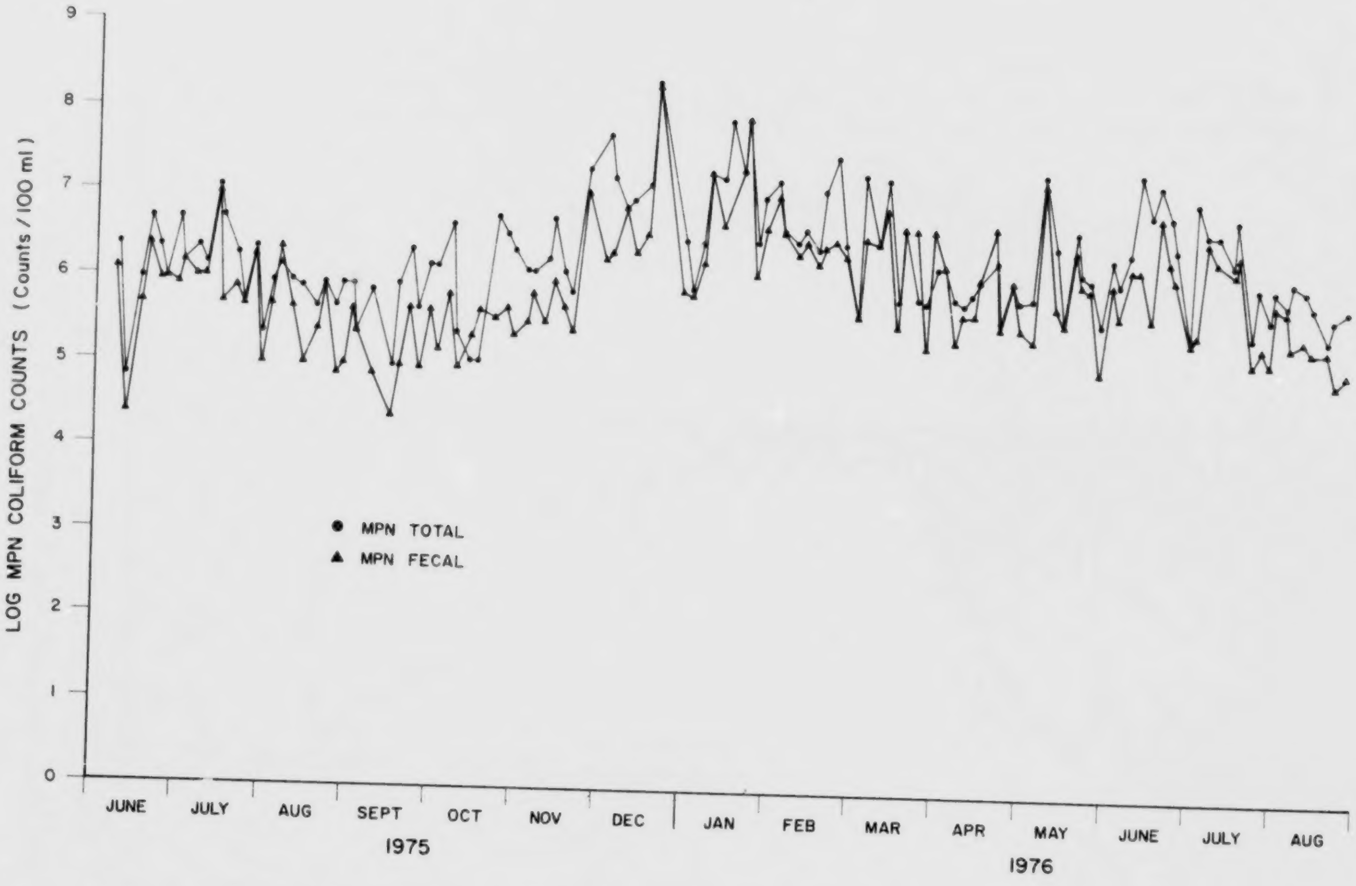

Figure E-14. Seasonal MPN coliform counts at sample station No. 1.

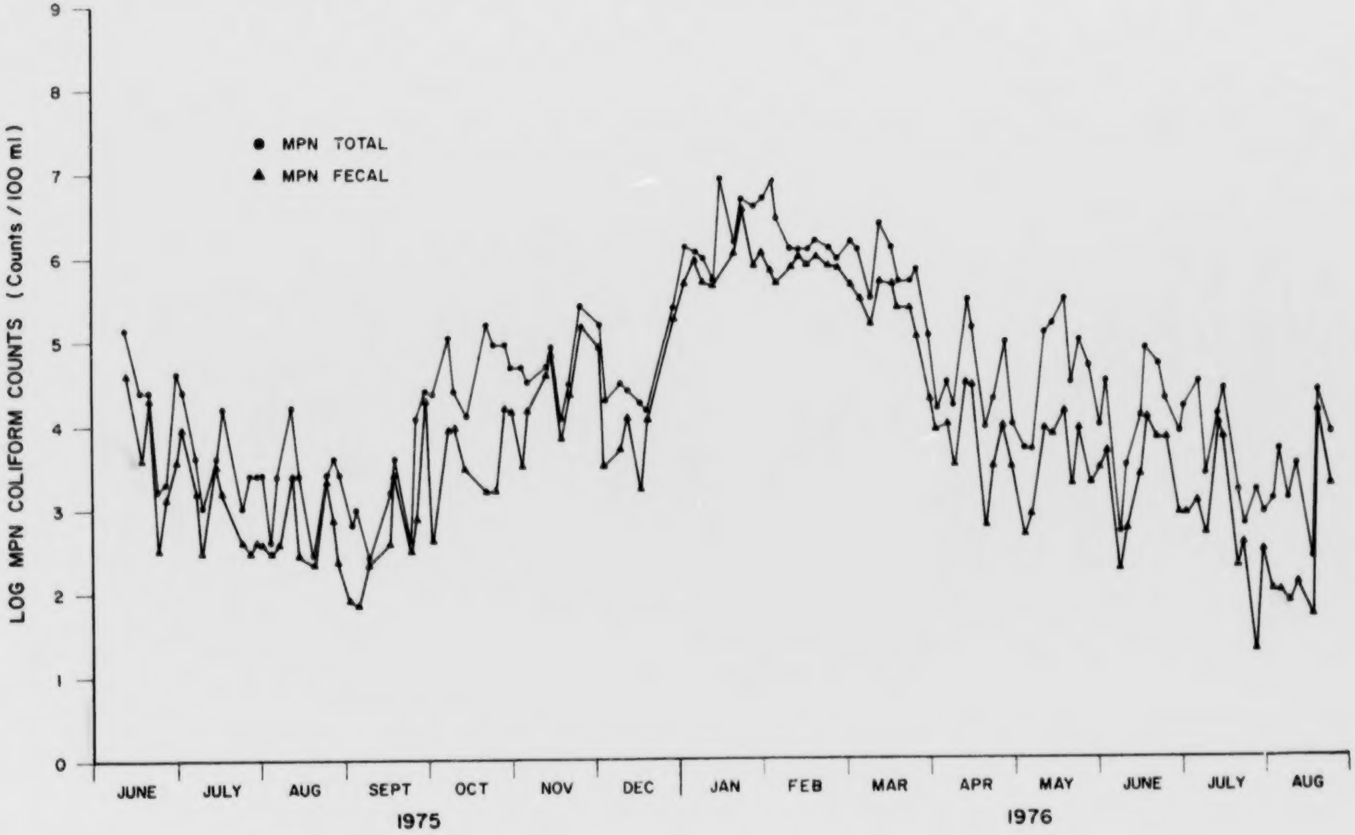

Figure E-15. Seasonal MPN coliform counts at sample station No. 2.

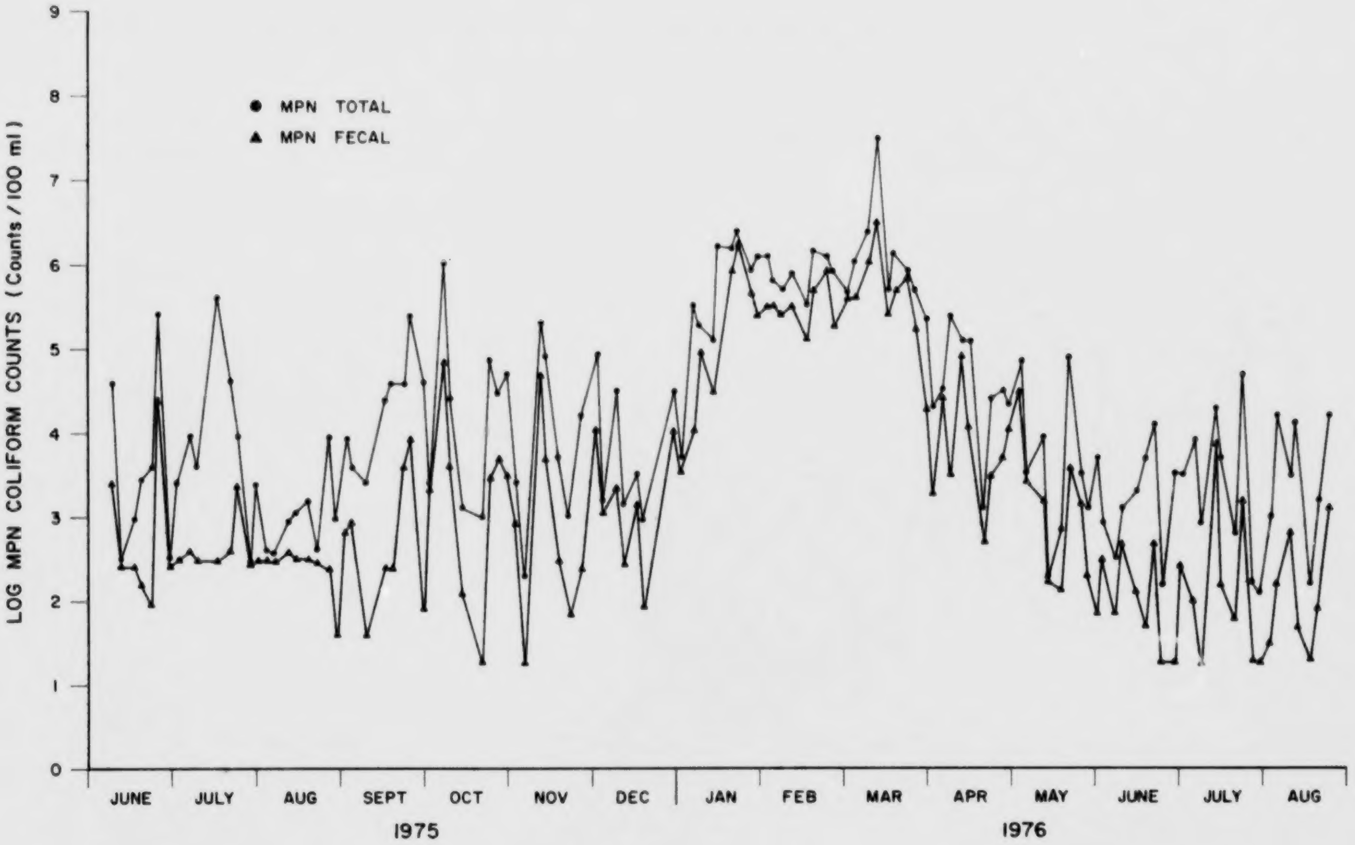

Figure E-16. Seasonal MPN coliform counts at sample station No. 3.

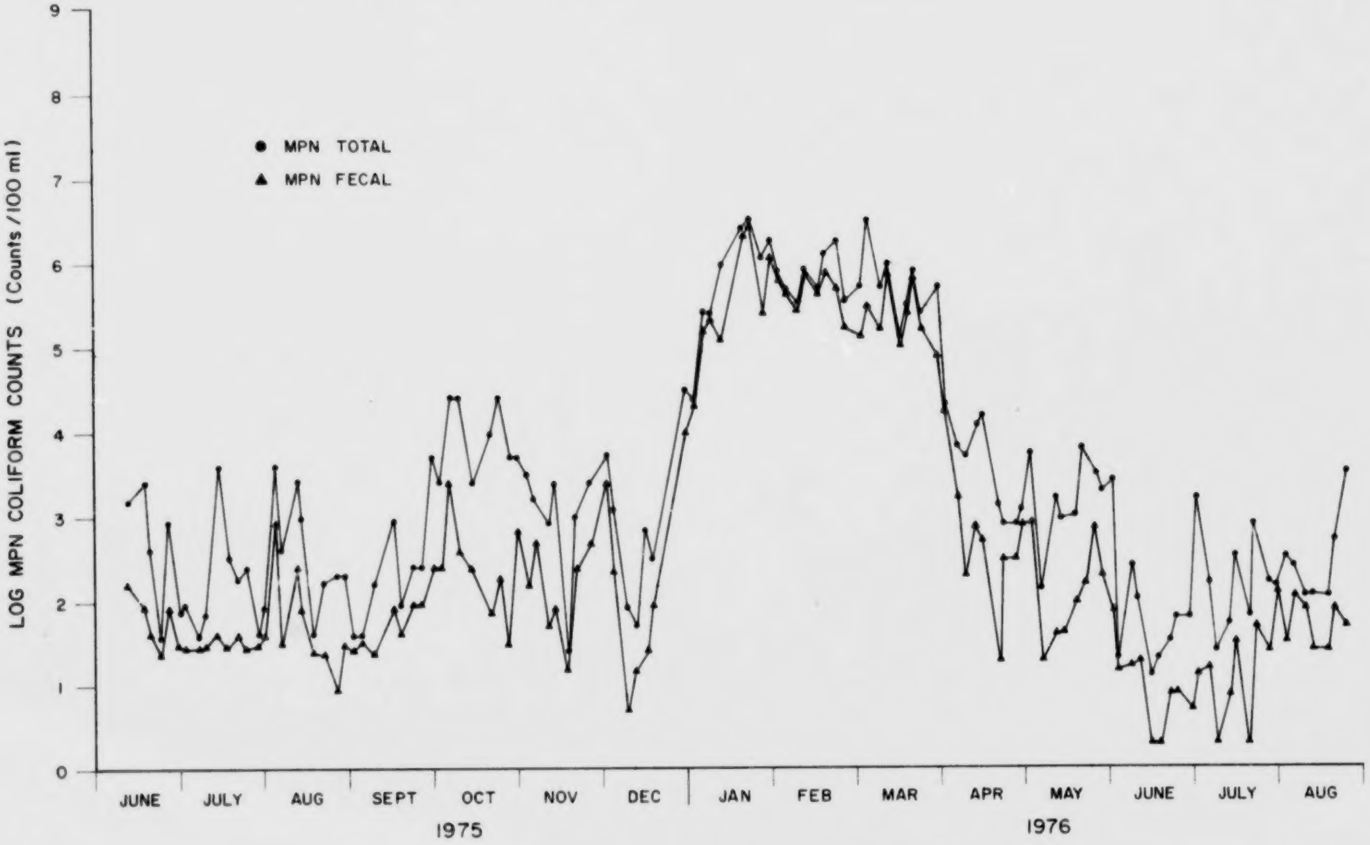

Figure E-17. Seasonal MPN coliform counts at sample station No. 4.

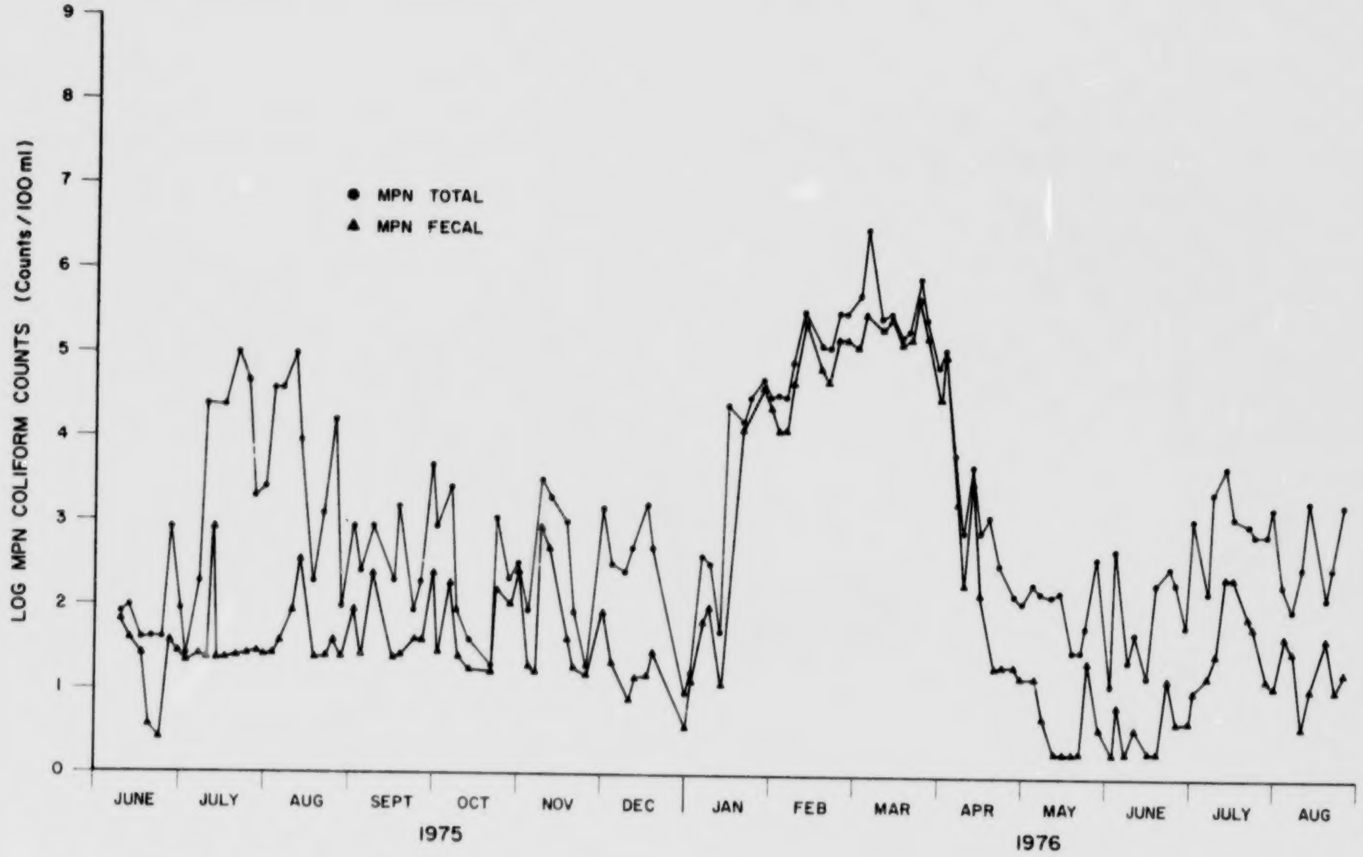

Figure E-18. Seasonal MPN coliform counts at sample station No. 5.

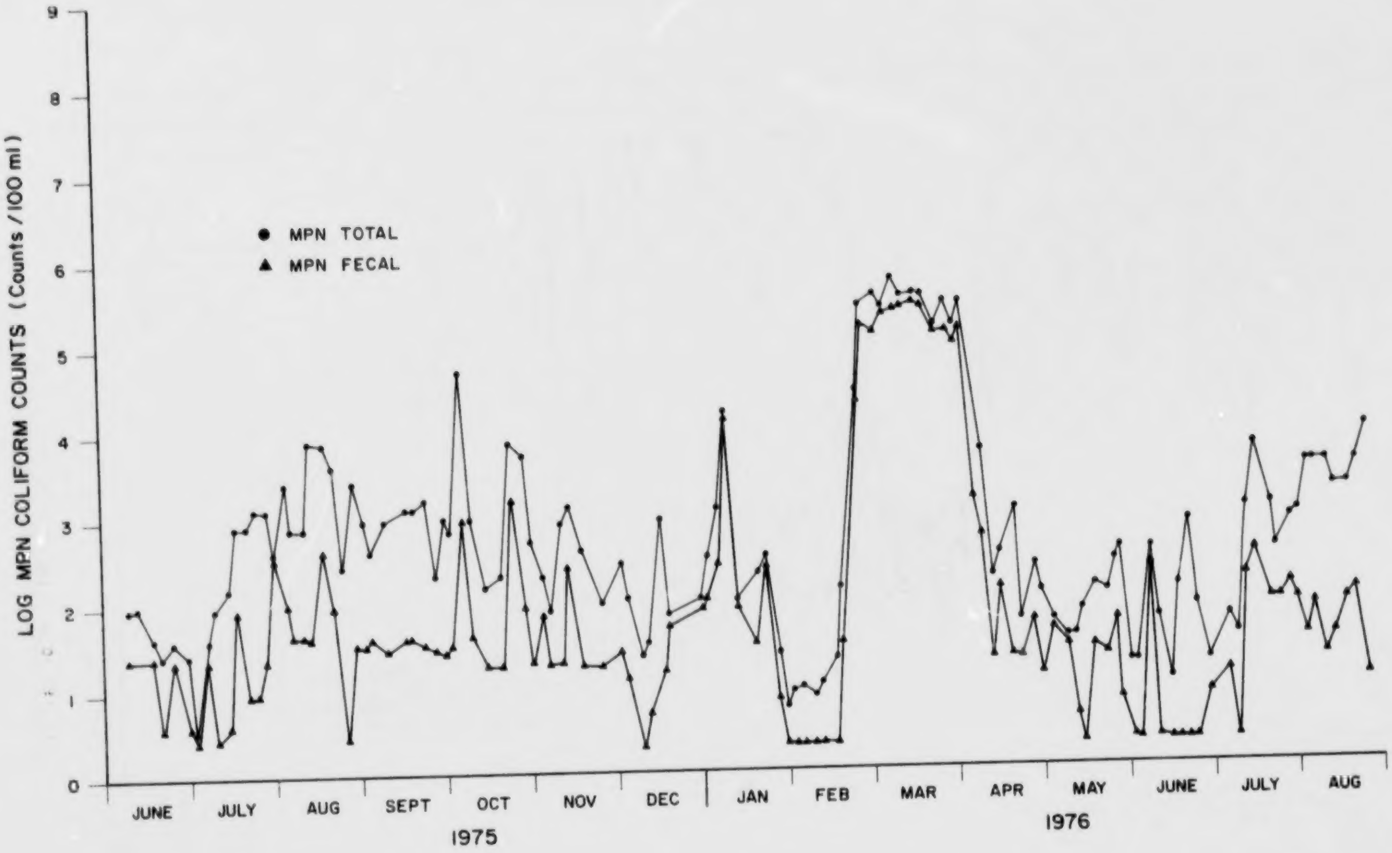

Figure E-19. Seasonal MPN coliform counts at sample station No. 6.

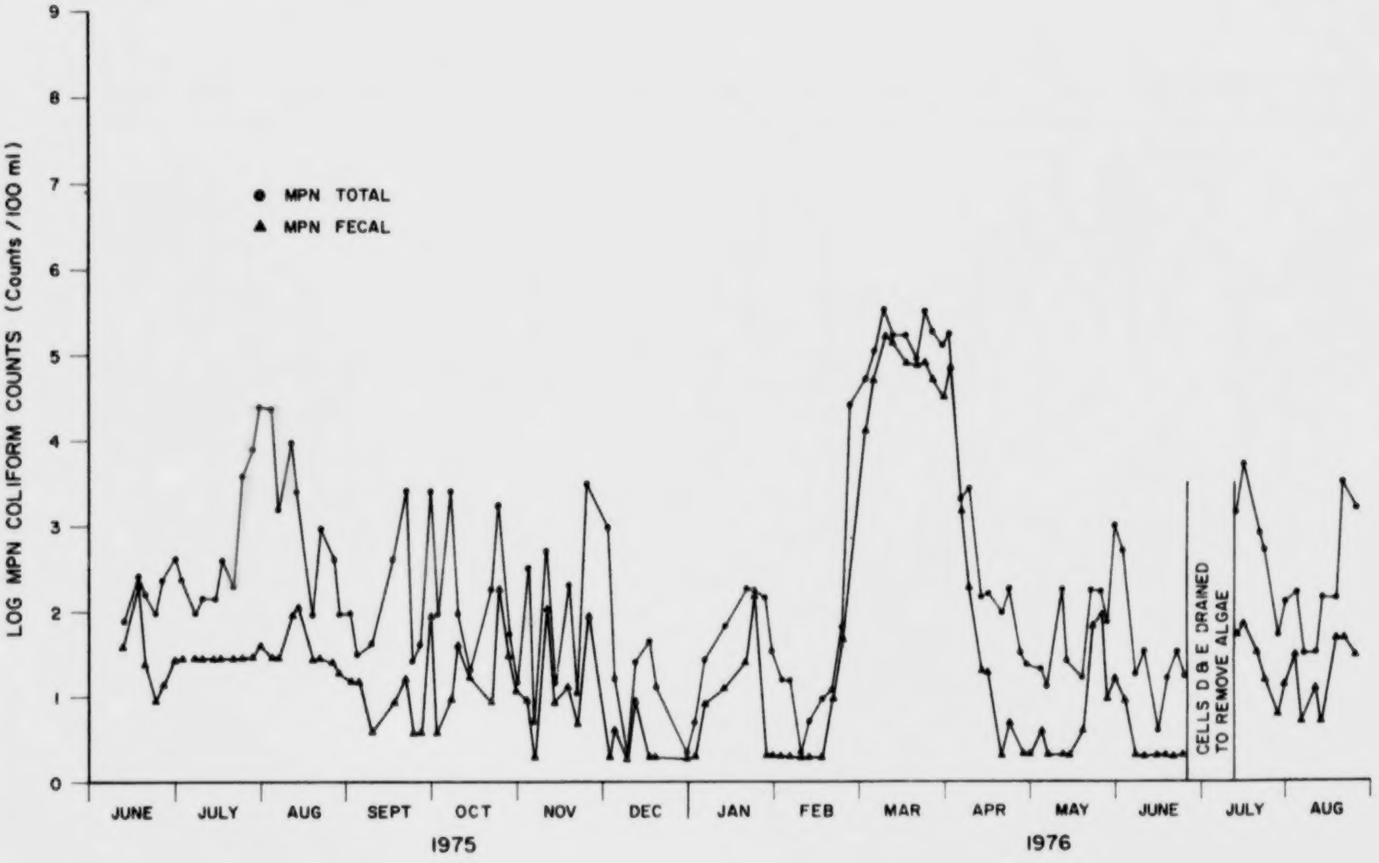

Figure E-20. Seasonal MPN coliform counts at sample station No. 7.

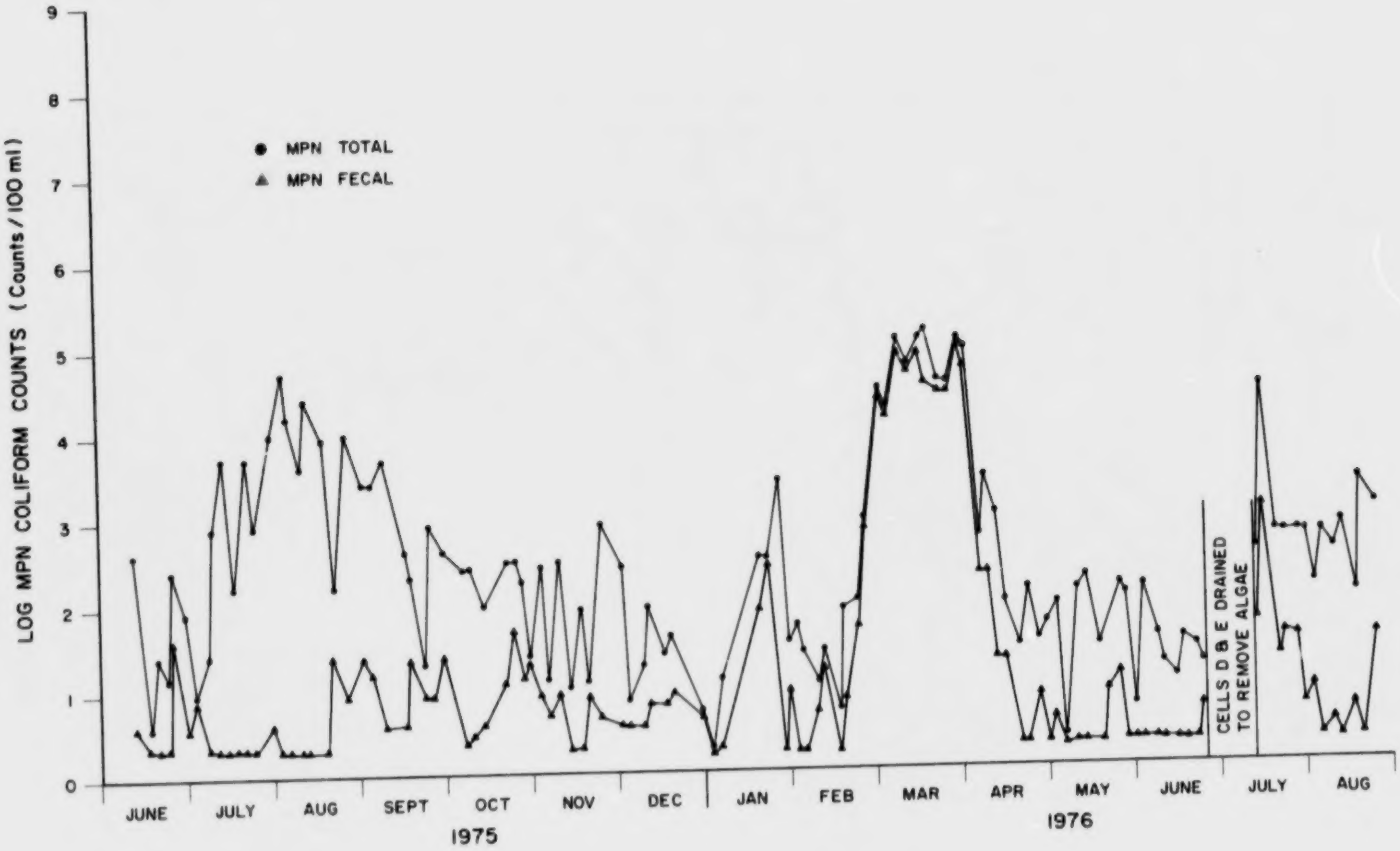

Figure E-21. Seasonal MPN coliform counts at sample station No. 8.

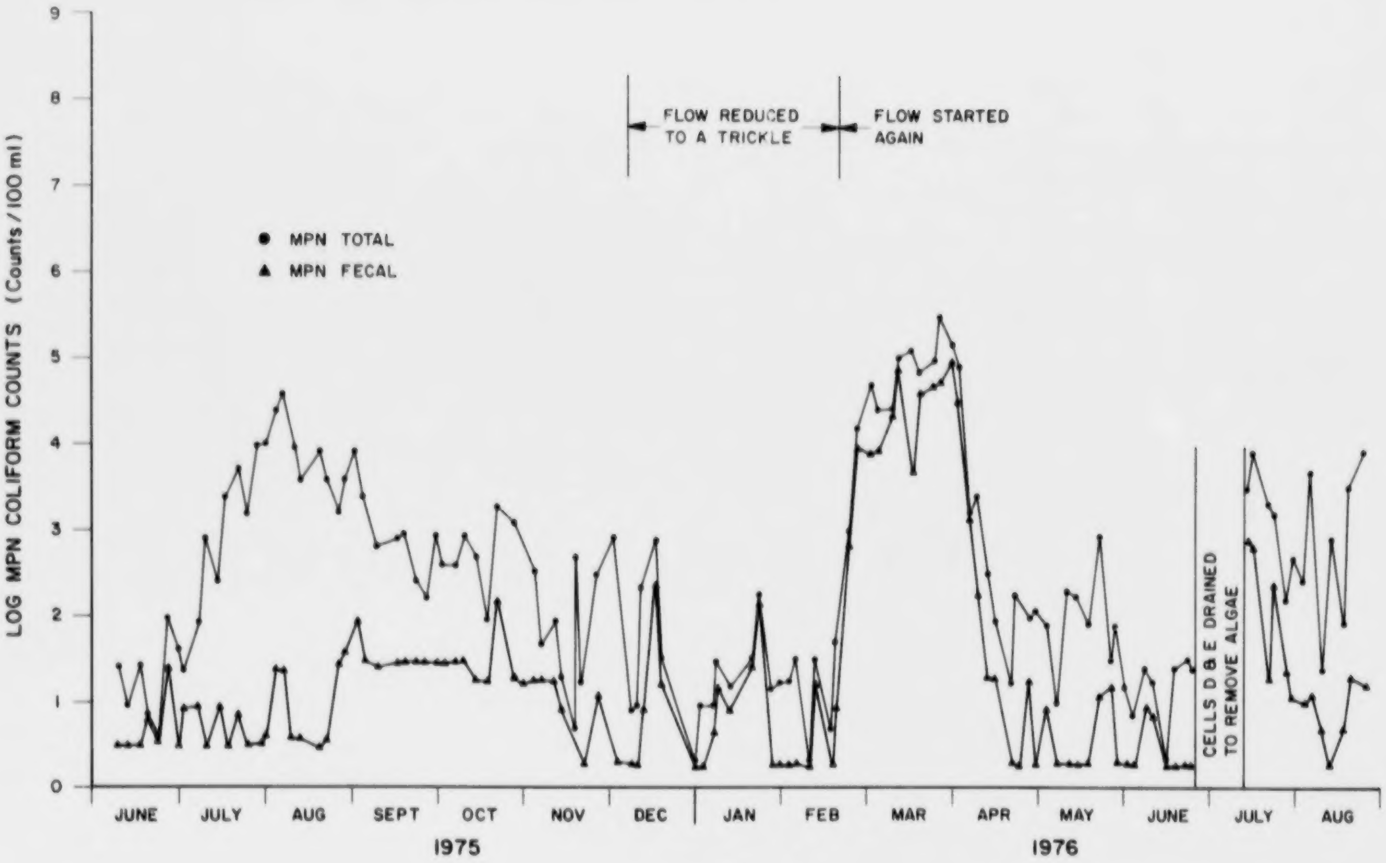

Figure E-22. Seasonal MPN coliform counts at sample station No. 9.

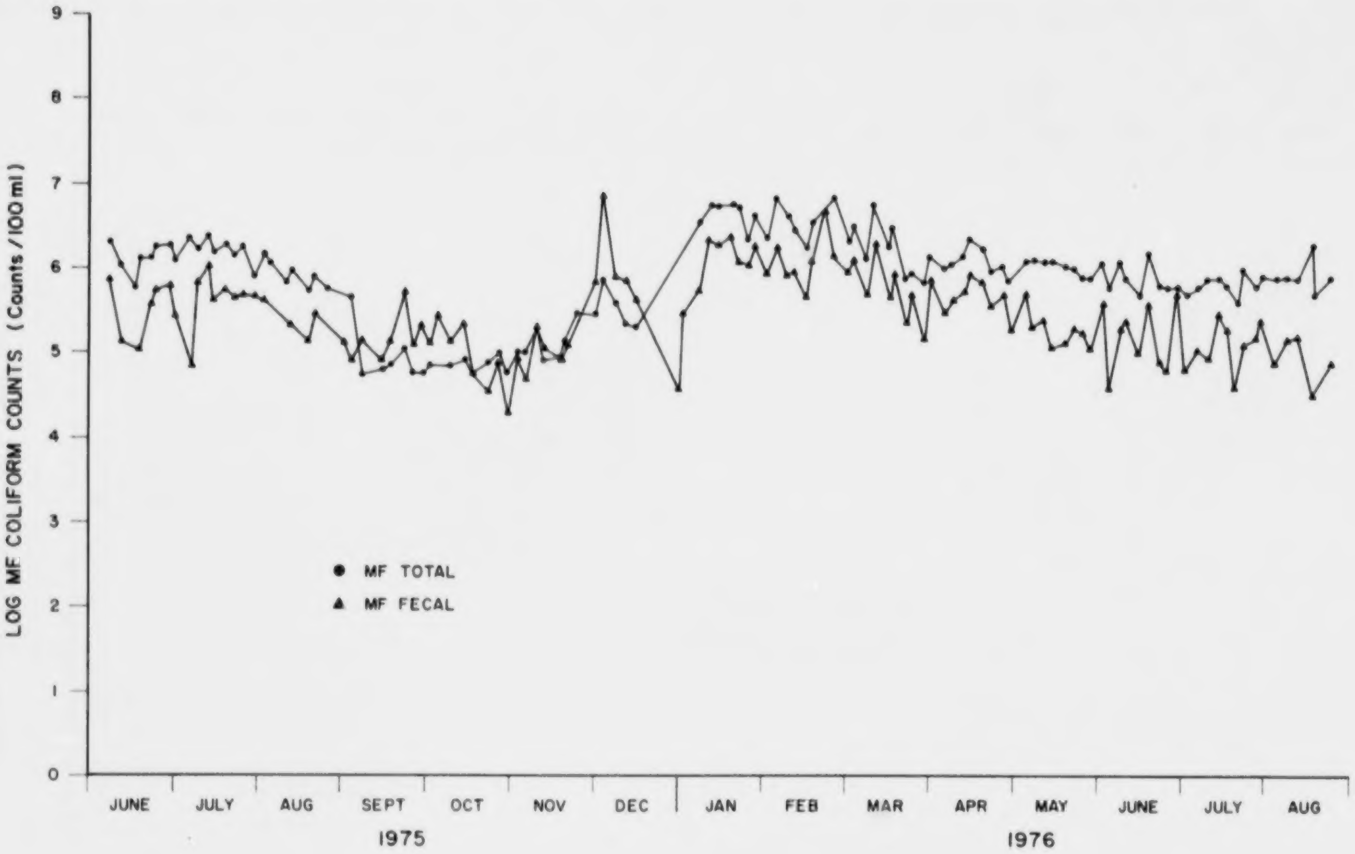

Figure E-23. Seasonal membrane filter coliform counts at sample station No. 1.

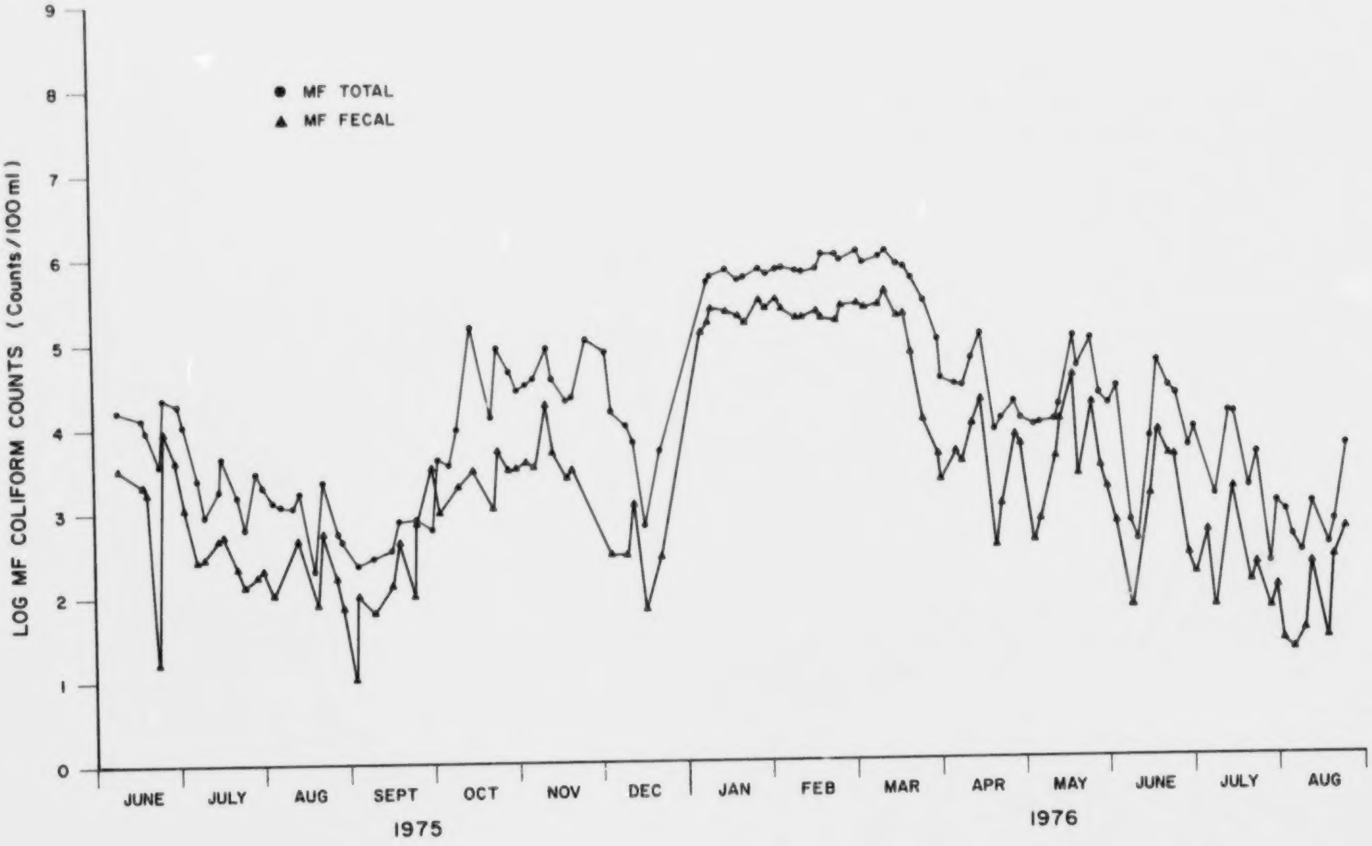

Figure E-24. Seasonal membrane filter coliform counts at sample station No. 2.

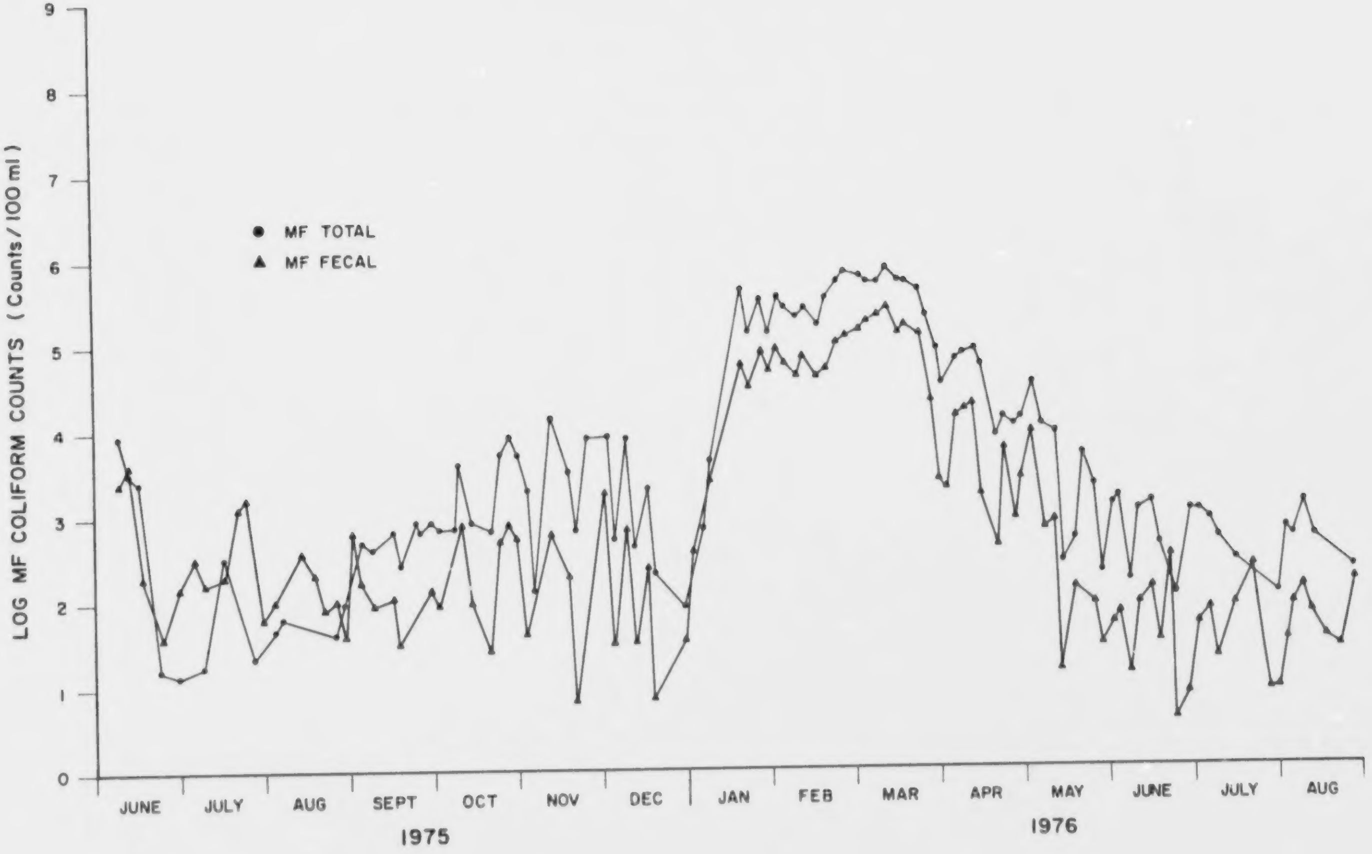

Figure E-25. Seasonal membrane filter coliform counts at sample station No. 3.

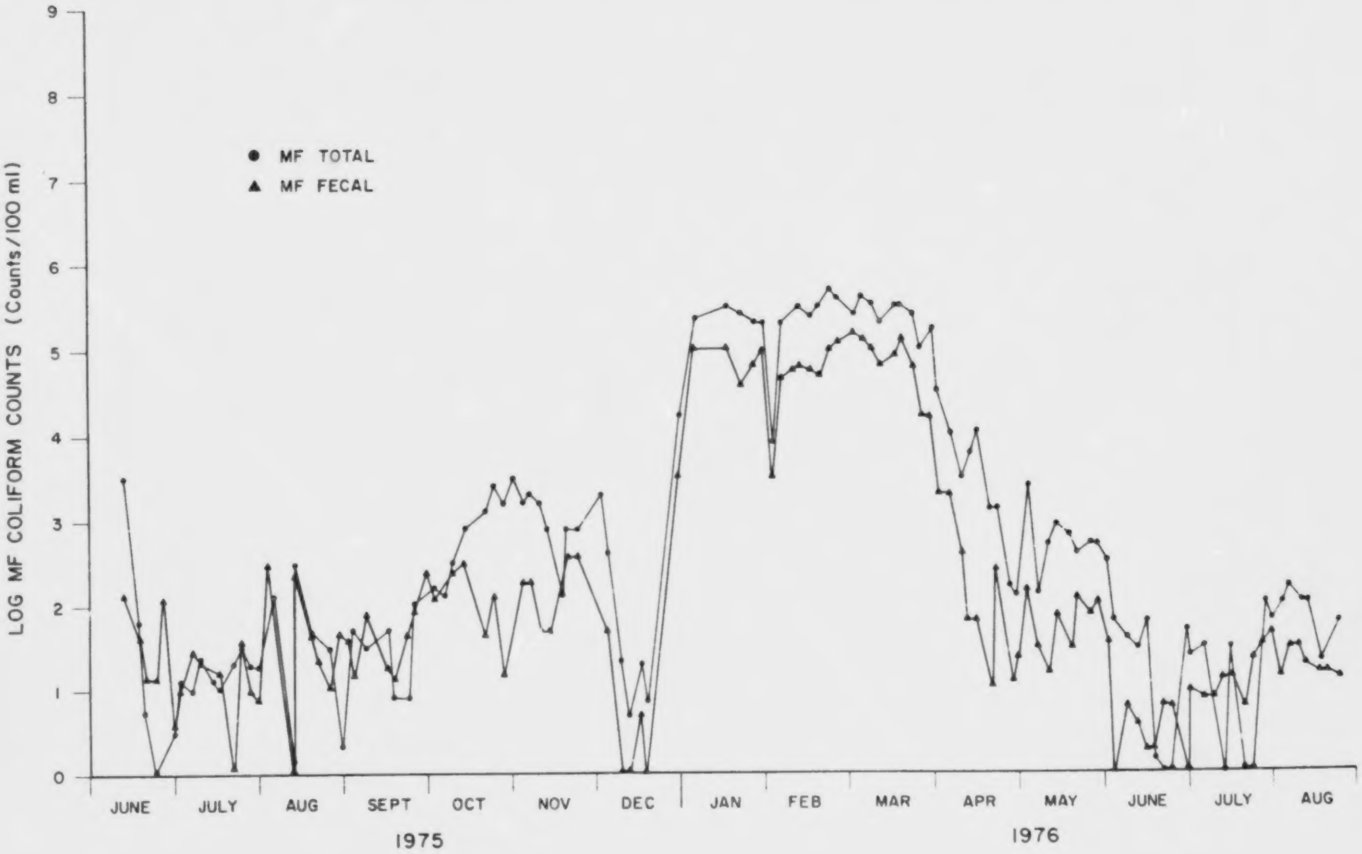

Figure E-26. Seasonal membrane filter coliform counts at sample station No. 4.

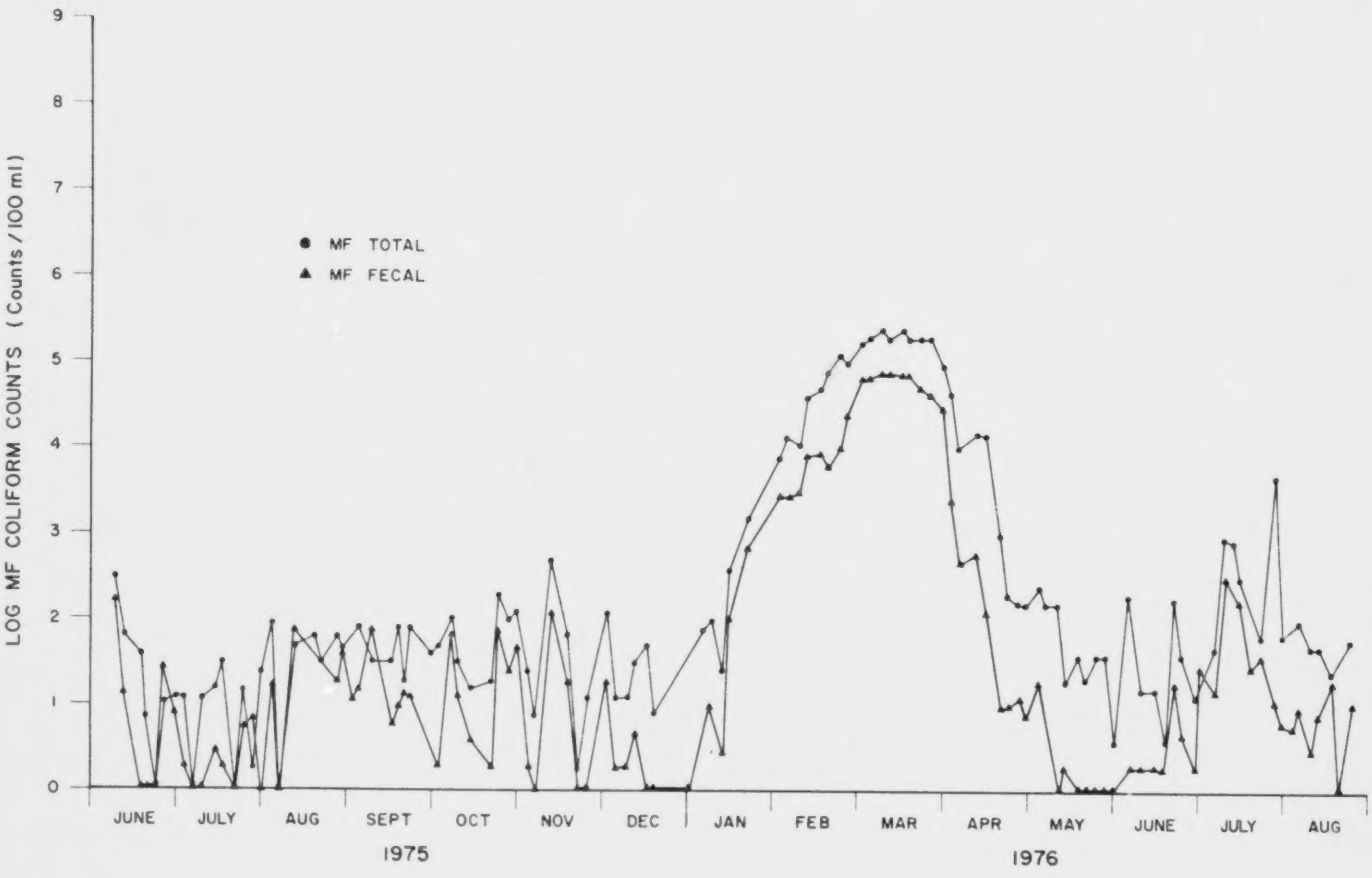

Figure E-27. Seasonal membrane filter coliform counts at sample station No. 5.

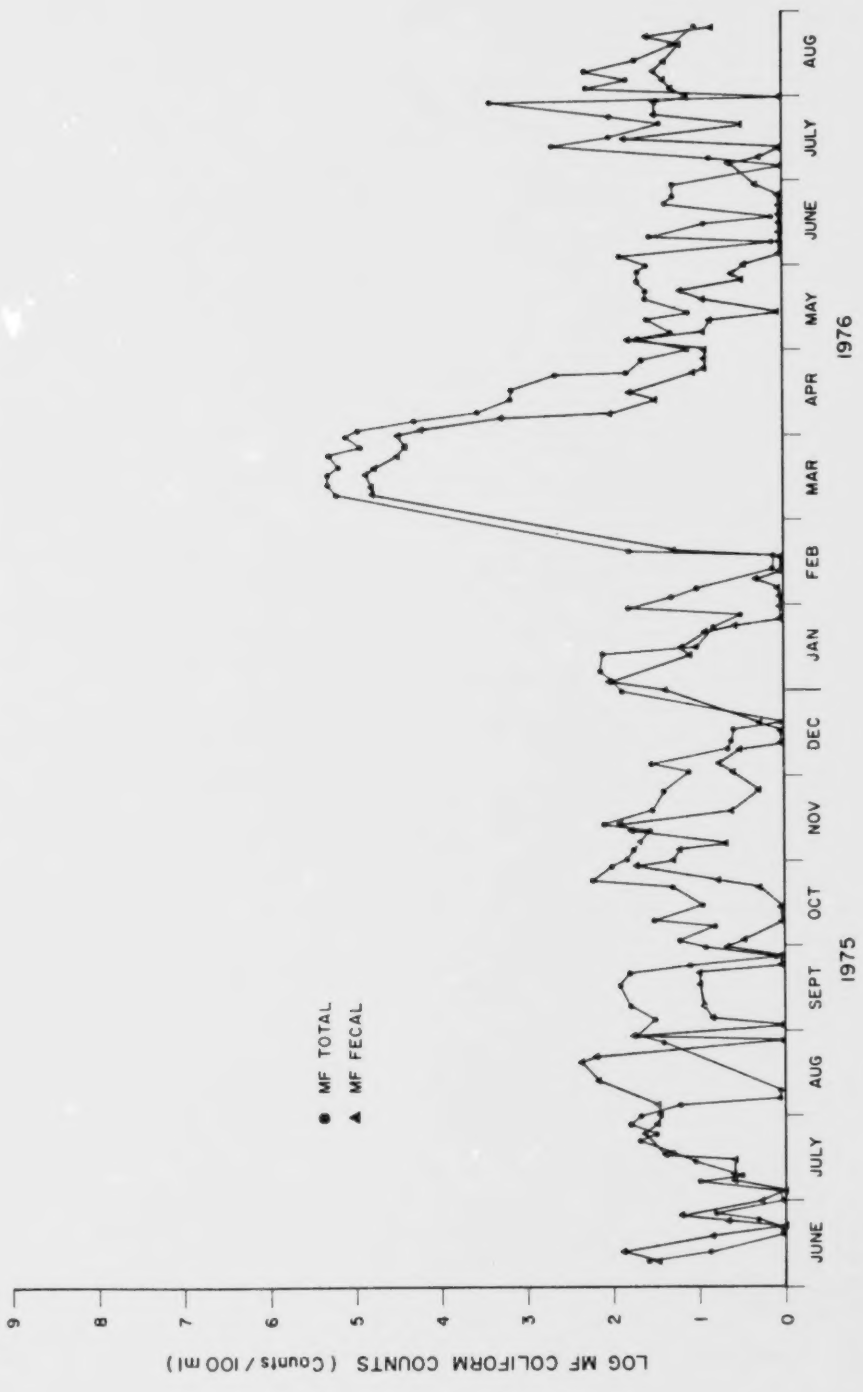

Figure E-28. Seasonal membrane filter coliform counts at sample station No. 6.

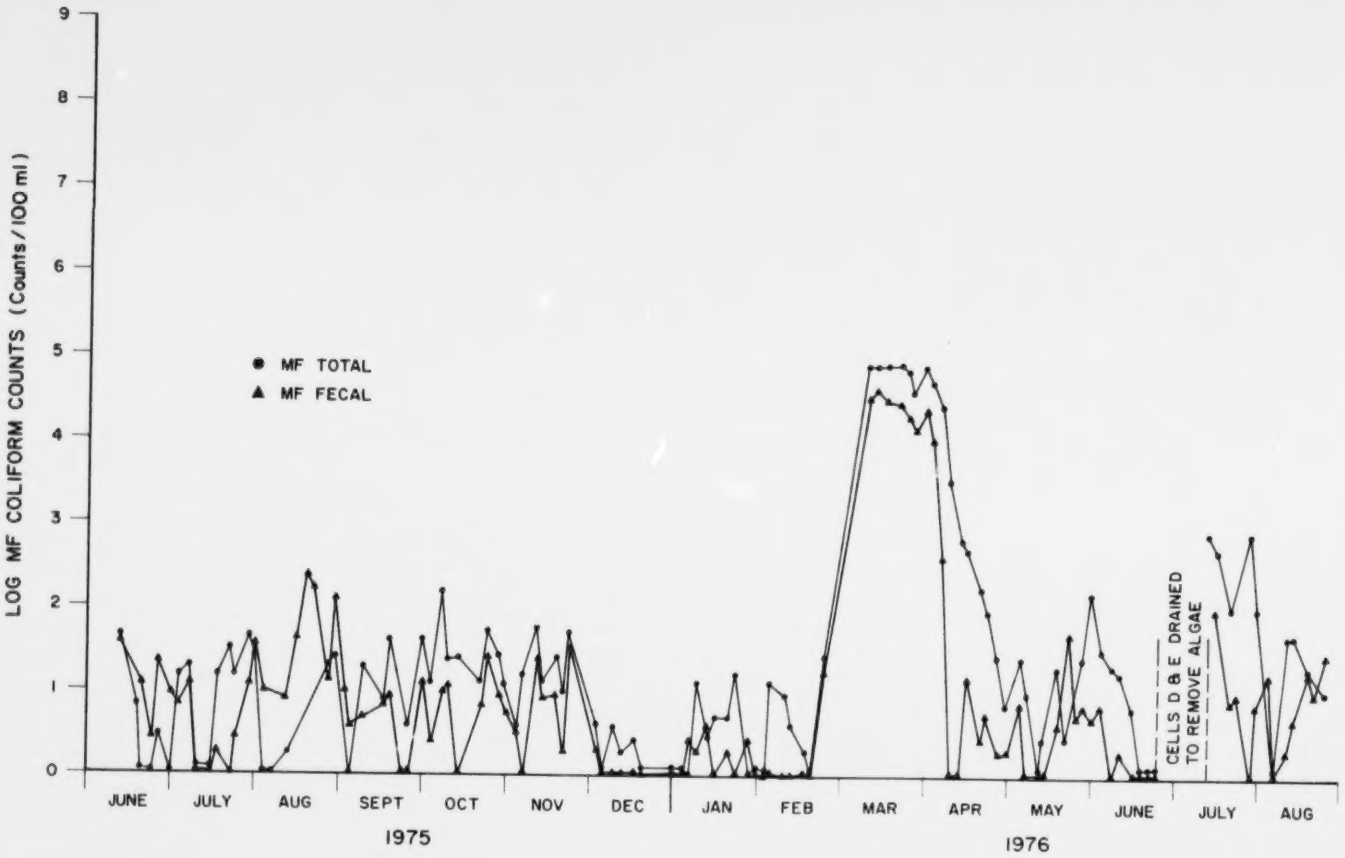

Figure E-29. Seasonal membrane filter coliform counts at sample station No. 7.

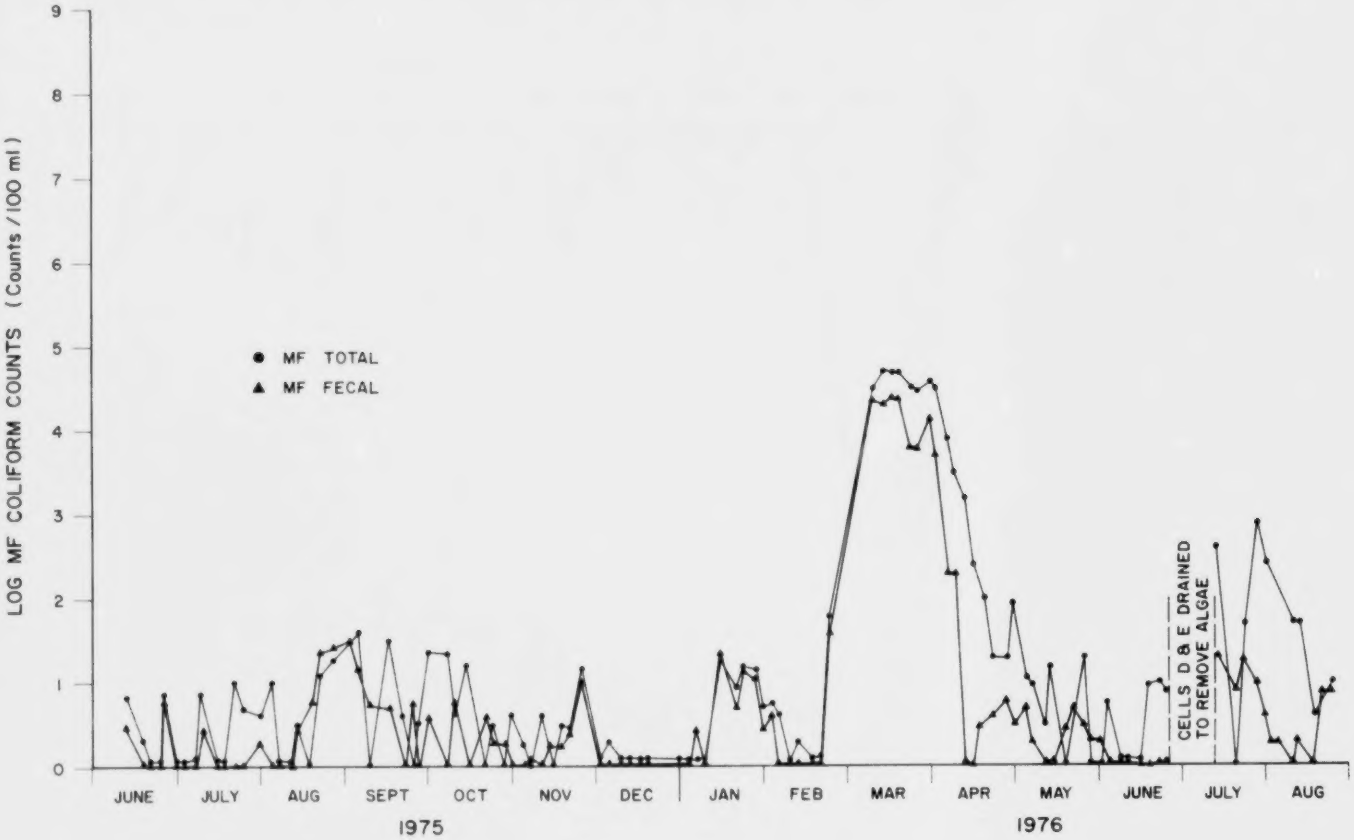

Figure E-30. Seasonal membrane filter coliform counts at sample station No. 8.

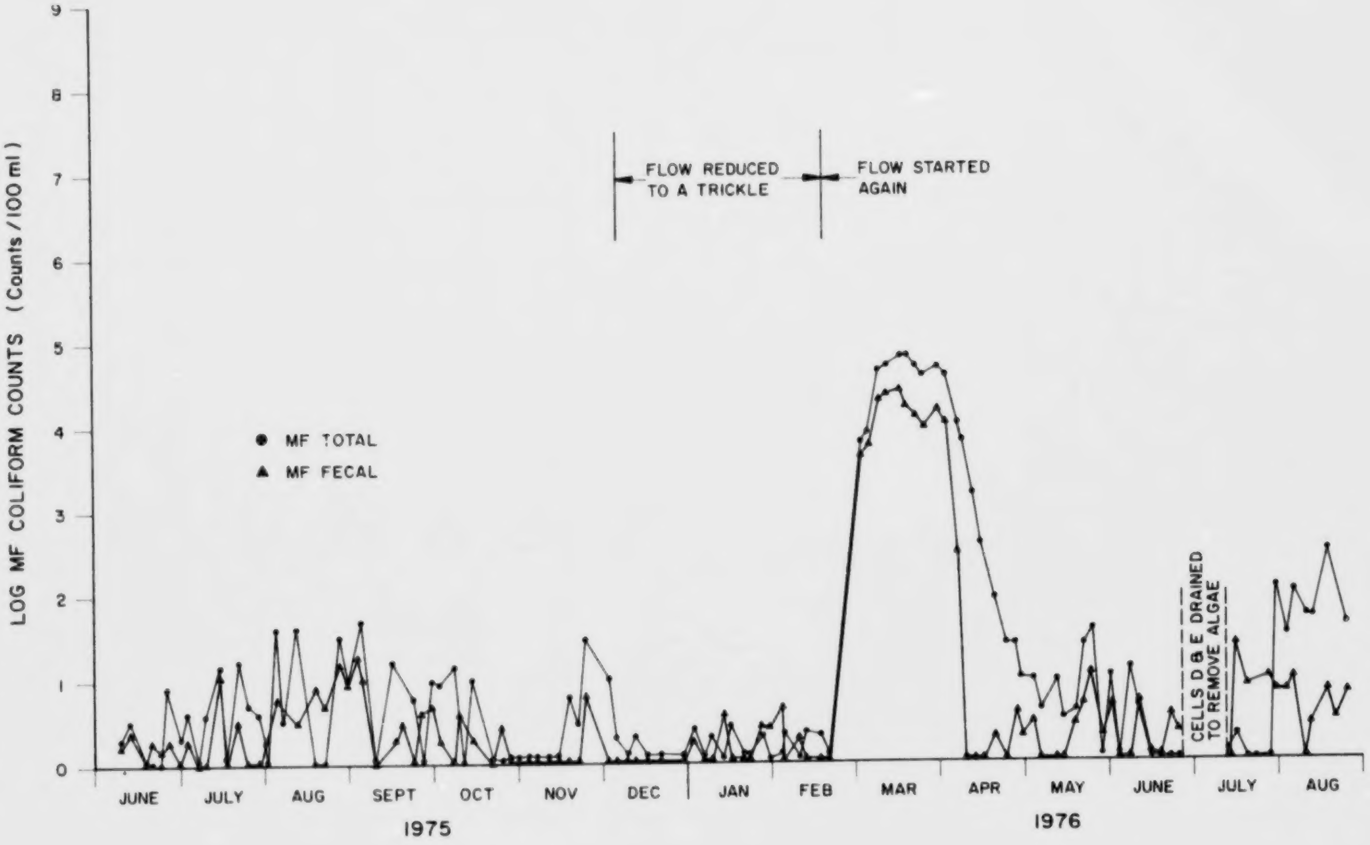

Figure E-31. Seasonal membrane filter coliform counts at sample station No. 9.

TABLE E-1. WASTE STABILIZATION LAGOON PERFORMANCE EVALUATION DATA COLLECTED FROM JUNE 1, 1975 TO AUGUST 24, 1976.

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L
6	9	75	1	2400000.	1100000.	2200000.	760000.	******	******	*****	*****	******	*****	****	****	****	****
6	9	75	3	39000.	2300.	8600.	2700.					******	*****	****	****	****	****
6	9	75	5	75.	93.	340.	170.					******	*****	****	****	****	****
6	9	75	6	93.	23.	38.	31.					******	*****	****	****	****	****
6	9	75	9	23.	3.	2.	2.	******	******	*****	*****	******	*****	****	****	****	****
6	12	75	1	64000.	23000.	1000000.	140000.	******	******	*****	*****	******	*****	****	****	****	****
6	12	75	2	150000.	39000.	16000.	3400.					******	*****	****	****	****	****
6	12	75	3	300.	300.	3500.	4000.					******	*****	****	****	****	****
6	12	75	4	1500.	150.	3000.	140.					******	*****	****	****	****	****
6	12	75	5	93.	43.	64.	14.					******	*****	****	****	****	****
6	12	75	6	93.	230.	7.	90.					******	*****	****	****	****	****
6	12	75	7	75.	43.	45.	39.					******	*****	****	****	****	****
6	12	75	8	390.	4.	7.	3.					******	*****	****	****	****	****
6	12	75	9	9.	3.	3.	3.	******	******	*****	*****	******	*****	****	****	****	****
6	17	75	1	930000.	430000.	570000.	100000.	******	******	17.18	*****	7.40	5.66	****	****	****	****
6	17	75	2	23000.	4300.	13000.	2200.					42.78	36.98	****	****	****	****
6	17	75	3	930.	230.	2300.	200.					45.78	32.41	****	****	****	****
6	17	75	4	2300.	90.	64.	48.					49.22	29.61	****	****	****	****
6	17	75	5	40.	30.	44.	1.					22.68	11.90	****	****	****	****
6	17	75	6	43.	23.	1.	7.					4.88	2.94	****	****	****	****
6	17	75	7	230.	230.	6.	130.					12.12	3.75	****	****	****	****
6	17	75	8	4.	3.	2.	1.					28.60	24.20	****	****	****	****
6	17	75	9	23.	3.	0.	1.	******	******	33.28	*****	34.80	21.60	****	****	****	****
6	19	75	1	4600000.	2400000.	1300000.	330000.	******	******	*****	2.28	16.20	11.20	****	****	****	****
6	19	75	2	23000.	23000.	9600.	1700.					38.40	32.30	****	****	****	****
6	19	75	3	2300.	150.	0.	80.					18.80	13.90	****	****	****	****
6	19	75	4	430.	40.	6.	15.					45.55	33.90	****	****	****	****
6	19	75	5	43.	4.	0.	7.					44.00	32.75	****	****	****	****
6	19	75	6	23.	4.	0.	1.					7.95	4.60	****	****	****	****
6	19	75	7	150.	23.	1.	12.					12.70	5.40	****	****	****	****
6	19	75	8	23.	3.	0.	0.					8.60	4.75	****	****	****	****
6	19	75	9	7.	7.	0.	2.	******	******	*****	3.16	7.85	3.00	****	****	****	****
6	23	75	1	2400000.	930000.	1400000.	530000.	13.68	******	13.99	*****	15.77	14.49	4.6	7.12	****	****
6	23	75	2	1500.	300.	3600.	50.					26.20	25.04	15.0	7.50	****	****
6	23	75	3	3900.	90.	17.	44.					14.23	11.49	8.9	7.15	****	****
6	23	75	4	40.	30.	1.	18.					13.09	8.37	7.9	7.20	****	****
6	23	75	5	39.	3.	1.	0.					6.63	5.89	9.1	7.33	****	****
6	23	75	6	23.	4.	2.	5.					7.23	5.71	8.2	7.29	****	****
6	23	75	7	93.	9.	1.	3.					6.23	4.97	6.7	7.28	****	****
6	23	75	8	15.	3.	0.	0.					3.83	3.29	6.2	7.28	****	****
6	23	75	9	4.	4.	0.	2.	******	39.43	*****	*****	7.46	4.20	7.4	7.20	****	****
6	25	75	1	930000.	930000.	1800000.	640000.	11.88	******	*****	2.04	14.54	13.17	5.4	7.50	12.0	5.5
6	25	75	2	2100.	1500.	22000.	8800.					19.31	30.70	19.5	7.90	17.0	0.9
6	25	75	3	240000.	24000.	1.	0.					12.49	11.57	8.3	7.70	17.0	0.8
6	25	75	4	930.	90.	27.	120.					17.97	14.00	17.0	8.30	17.0	3.0
6	25	75	5	940.	43.	11.	29.					14.60	6.57	15.0	7.90	17.0	1.2
6	25	75	6	43.	23.	6.	18.					******	*****	****	****	17.0	2.3
6	25	75	7	230.	15.	3.	27.					9.29	4.94	12.0	8.10	17.0	2.5

TABLE F-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L
6	25	75	8	230.	43.	7.	8.					9,91	4,37	14,5	8,10	17,0	2,9
6	25	75	9	93.	23.	2.	8.	******	******	*****	3,22	12,94	5,34	15,0	8,10	17,0	2,5
6	30	75	1	4600000.	750000.	1800000.	570000.	11,70	******	*****	4,66	11,00	11,40	3,2	7,83	****	****
6	30	75	2	43000.	4300.	19000.	3900.					33,04	32,88	15,0	8,40	****	****
6	30	75	3	300.	300.	12.	150.					3,77	4,86	5,8	7,95	****	****
6	30	75	4	70.	30.	3.	4.					8,97	8,31	8,8	8,19	****	****
6	30	75	5	90.	30.	12.	8.					5,80	4,77	7,9	8,00	****	****
6	30	75	6	23.	4.	0.	2.					4,74	4,89	6,9	8,15	****	****
6	30	75	7	430.	30.	0.	10.					8,83	5,66	7,5	8,18	****	****
6	30	75	8	75.	4.	0.	0.					6,40	4,23	7,4	8,18	****	****
6	30	75	9	43.	3.	2.	1.	******	******	*****	3,78	11,83	5,09	11,0	8,19	****	****
7	2	75	1	1500000.	1500000.	1300000.	280000.	******	******	*****	*****	******	*****	****	****	****	****
7	2	75	2	23000.	9300.	11000.	1300.					******	*****	****	****	****	****
7	2	75	3	2300.	300.	2.	91.					******	*****	****	****	****	****
7	2	75	4	90.	30.	12.	10.					******	*****	****	****	****	****
7	2	75	5	30.	30.	12.	2.					******	*****	****	****	****	****
7	2	75	6	3.	3.	1.	1.					******	*****	****	****	****	****
7	2	75	7	230.	30.	16.	6.					******	*****	****	****	****	****
7	2	75	8	9.	9.	0.	0.					******	*****	****	****	****	****
7	2	75	9	23.	9.	4.	2.	******	******	*****	*****	******	*****	****	****	****	****
7	7	75	1	2400000.	930000.	2300000.	76000.	10,80	74,50	14,80	1,74	22,11	20,43	5,4	7,50	14,0	7,4
7	7	75	2	4300.	1500.	2400.	250.					21,55	21,44	13,0	8,38	23,0	6,4
7	7	75	3	9300.	400.	0.	280.					4,57	5,37	6,8	7,70	25,0	1,4
7	7	75	4	40.	30.	9.	33.					10,54	10,54	4,8	7,93	24,0	1,3
7	7	75	5	200.	30.	0.	1.					4,17	4,34	6,6	7,83	25,0	1,6
7	7	75	6	39.	23.	10.	4.					3,74	4,49	5,7	8,00	25,0	3,2
7	7	75	7	90.	30.	19.	13.					2,43	3,91	5,0	3,25	25,0	10,4
7	7	75	8	23.	3.	0.	1.					8,80	7,26	7,1	8,20	25,0	9,2
7	7	75	9	93.	9.	0.	0.	******	36,20	34,80	2,55	8,86	7,46	6,2	8,10	25,0	9,3
7	9	75	1	1500000.	930000.	1600000.	760000.	10,70	******	9,90	*****	10,37	9,40	3,4	7,25	****	****
7	9	75	2	900.	300.	900.	260.					******	*****	****	****	****	****
7	9	75	3	4300.	300.	15.	170.					******	*****	****	****	****	****
7	9	75	4	70.	30.	23.	24.					******	*****	****	****	****	****
7	9	75	5	24000.	30.	12.	1.					******	*****	****	****	****	****
7	9	75	6	93.	3.	3.	4.					******	*****	****	****	****	****
7	9	75	7	140.	30.	1.	0.					******	*****	****	****	****	****
7	9	75	8	930.	3.	7.	3.					******	*****	****	****	****	****
7	9	75	9	750.	3.	4.	1.	******	******	*****	*****	******	*****	****	****	****	****
7	14	75	1	11000000.	11000000.	2400000.	1200000.	24,00	55,10	20,10	1,79	16,70	13,69	6,8	7,20	****	****
7	14	75	2	4300.	4300.	1800.	440.					******	*****	****	****	****	****
7	14	75	3	0.	0.	0.	0.					******	*****	****	****	****	****
7	14	75	4	4300.	40.	6.	12.					******	*****	****	****	****	****
7	14	75	5	9400.	30.	15.	3.					******	*****	****	****	****	****
7	14	75	6	150.	4.	11.	4.					******	*****	****	****	****	****
7	14	75	7	150.	30.	1.	0.					******	*****	****	****	****	****
7	14	75	8	4600.	3.	0.	1.					******	*****	****	****	****	****
7	14	75	9	230.	9.	15.	13.	******	******	*****	*****	******	*****	****	****	****	****
7	16	75	4	600000.	430000.	1900000.	460000.					8,54	9,46	****	7,60	15,0	5,4

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L
7	16	75	2	15000.	1500.	4300.	500.					******	*****	****	9,13	22,0	19,2
7	16	75	3	460000.	300.	2.	220.					******	*****	****	8,64	22.0	7,4
7	16	75	4	280.	30.	9.	18.					******	*****	****	8,70	23.0	8,1
7	16	75	5	24000.	30.	34.	2.					******	*****	****	8,15	24,0	2,8
7	16	75	6	930.	93.	19.	24.					******	*****	****	8,16	24,0	2,9
7	16	75	7	430.	30.	16.	2.					******	*****	****	8,23	23,0	4,5
7	16	75	8	150.	3.	0.	0.					******	*****	****	8,23	23.0	3,8
7	16	75	9	2400.	3,	0.	1.	******	******	*****	*****	******	*****	****	8,22	23,0	3,3
7	21	75	1	1500000.	750000.	1700000.	620000.	******	******	*****	*****	******	*****	****	****	****	****
7	21	75	2	900.	400.	1500.	200.					******	*****	****	****	****	****
7	21	75	3	43000.	400.	0.	1100.					******	*****	****	****	****	****
7	21	75	4	210.	40.	20.	1.					******	*****	****	****	****	****
7	21	75	5	110000.	30.	0.	1.					******	*****	****	****	****	****
7	21	75	6	750.	9.	49.	0.					******	*****	****	****	****	****
7	21	75	7	210.	30.	29.	0.					******	*****	****	****	****	****
7	21	75	8	4600.	3.	10.	0.					******	*****	****	****	****	****
7	21	75	9	4600.	7.	16.	3.	******	******	*****	*****	******	*****	****	****	****	****
7	23	75	1	430000.	430000.	1400000.	480000.	******	******	*****	*****	******	*****	****	****	****	****
7	23	75	2	2300.	300.	600.	120.					******	*****	****	****	****	****
7	23	75	3	9300.	2300.	5.	1600.					******	*****	****	****	****	****
7	23	75	4	2300.	30.	32.	40.					******	*****	****	****	****	****
7	23	75	5	46000.	30.	17.	6.					******	*****	****	****	****	****
7	23	75	6	1500.	9.	31.	45.					******	*****	****	****	****	****
7	23	75	7	4300.	30.	17.	3.					******	*****	****	****	****	****
7	23	75	8	750.	3.	5.	1.					******	*****	****	****	****	****
7	23	75	9	1500.	3.	35.	3.	******	******	*****	*****	******	*****	****	****	****	****
7	28	75	1	2400000.	2400000.	1700000.	500000.	******	******	*****	*****	******	*****	****	****	****	****
7	28	75	2	2300.	400.	2700.	160.					******	*****	****	****	****	****
7	28	75	3	300.	300.	21.	0.					******	*****	****	****	****	****
7	28	75	4	40.	30.	20.	10.					******	*****	****	****	****	****
7	28	75	5	2100.	30.	2.	7.					******	*****	****	****	****	****
7	28	75	6	1500.	23.	59.	34.					******	*****	****	****	****	****
7	28	75	7	7500.	30.	45.	13.					******	*****	****	****	****	****
7	28	75	9	11000.	3.	4.	0.	******	******	*****	*****	******	*****	****	****	****	****
7	30	75	1	230000.	93000.	800000.	480000.	12,30	33,50	*****	*****	6,06	5,06	****	****	****	****
7	30	75	2	2300.	400.	2000.	200.					******	*****	****	****	****	****
7	30	75	3	2300.	300.	0.	67.					******	*****	****	****	****	****
7	30	75	4	90.	40.	20.	8.					******	*****	****	****	****	****
7	30	75	5	2300.	30.	25.	0.					******	*****	****	****	****	****
7	30	75	6	430.	430.	50.	30.					******	*****	****	****	****	****
7	30	75	7	24000.	40.	22.	37.					******	*****	****	****	****	****
7	30	75	8	11000.	4.	4.	2.					******	*****	****	****	****	****
7	30	75	9	11000.	4.	0.	2.	******	******	*****	*****	******	*****	****	****	****	****
8	4	75	1	930000.	430000.	1400000.	440000.	******	******	*****	*****	******	*****	****	****	****	****
8	4	75	2	400.	300.	1200.	96.					******	*****	****	****	****	****
8	4	75	3	400.	300.	46.	100.					******	*****	****	****	****	****
8	4	75	4	4300.	760.	2.	360.					******	*****	****	****	****	****
8	4	75	5	43000.	30.	91.	18.					******	*****	****	****	****	****

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L
8	4	75	6	2400.	93.	15.	32.					******	*****	****	****	****	****
8	4	75	7	24000.	30.	0.	11.					******	*****	****	****	****	****
8	4	75	8	46000.	3.	10.	0.					******	*****	****	****	****	****
8	4	75	9	24000.	23.	37.	6.	******	******	*****	*****	******	*****	****	****	****	****
8	6	75	1	1500000.	2400000.	1200000.	0.	7,40	12,20	2,16	1,95	6,57	6,37	****	7,80	15.0	5.3
8	6	75	2	2300.	400.	1200.	0.					******	*****	****	8,00	21.0	****
8	6	75	3	300.	300.	68.	0.					******	*****	****	8,09	22.0	2,9
8	6	75	4	430.	30.	120.	0.					******	*****	****	8,69	22.0	12.7
8	6	75	5	43000.	40.	4.	0.					******	*****	****	8,21	22.0	4.6
8	6	75	6	750.	43.	1.	0.					******	*****	****	8,61	22.0	6.8
8	6	75	7	1500.	30.	0.	0.					******	*****	****	8,52	21.0	6.2
8	6	75	8	15000.	3.	0.	0.					******	*****	****	9,00	22.0	14.2
8	6	75	9	46000.	23.	0.	0.	******	******	*****	*****	******	*****	****	9,00	22.0	13.1
8	11	75	1	930000.	430000.	710000.	0.	5,45	******	*****	*****	7,63	6,71	****	7,62	15.5	4.7
8	11	75	2	15000.	2300.	1100.	0.					******	*****	****	7,70	21.0	20.0
8	11	75	3	900.	400.	2.	0.					******	*****	****	7,93	22.0	20.0
8	11	75	4	930.	70.	0.	0.					******	*****	****	8,99	22.0	15.6
8	11	75	5	93000.	90.	0.	0.					******	*****	****	8,52	22.5	8.1
8	11	75	6	750.	43.	0.	0.					******	*****	****	9,00	22.0	11.0
8	11	75	7	9400.	90.	8.	0.					******	*****	****	9,00	21.0	20.0
8	11	75	8	4300.	30.	0.	0.					******	*****	****	9,18	21.5	20.0
8	11	75	9	7500.	4.	19.	0.	******	******	*****	*****	******	*****	****	9,12	21.5	13.7
8	13	75	1	750000.	93000.	850000.	220000.	7,38	45,06	78,34	0,77	6,51	6,17	****	7,54	15.5	4.5
8	13	75	2	2300.	300.	1600.	550.					******	*****	****	8,05	20.5	3.8
8	13	75	3	1100.	300.	3.	390.					******	*****	****	7,88	21.5	2.6
8	13	75	4	2300.	230.	0.	240.					******	*****	****	8,92	21.0	13.2
8	13	75	5	9400.	430.	51.	81.					******	*****	****	8,60	22.0	8.5
8	13	75	6	9300.	39.	0.	168.					******	*****	****	8,81	21.0	7.4
8	13	75	7	2300.	110.	2.	45.					******	*****	****	8,64	21.0	3.3
8	13	75	8	24000.	3.	3.	3.					******	*****	****	9,08	21.5	9.4
8	13	75	9	4300.	4.	41.	3.	******	******	*****	*****	******	*****	****	9,10	21.0	11.6
8	19	75	1	430000.	230000.	320000.	130000.	6,33	51,93	7,56	1,16	5,03	4,69	****	7,85	16.0	4.0
8	19	75	2	400.	300.	200.	73.					40,00	*****	****	8,22	20.5	5.4
8	19	75	3	1500.	300.	0.	192.					6,31	*****	****	8,18	20.5	4.2
8	19	75	4	40.	30.	0.	52.					37,67	*****	****	9,12	20.5	6.9
8	19	75	5	200.	30.	0.	59.					46,60	*****	****	9,30	21.0	12.4
8	19	75	6	7500.	430.	0.	128.					32,50	*****	****	9,42	20.5	10.0
8	19	75	7	90.	30.	1.	260.					32,47	*****	****	8,90	20.0	1.9
8	19	75	8	9300.	3.	0.	6.					30,14	*****	****	9,21	20.0	8.9
8	19	75	9	9300.	3.	0.	9.	******	******	*****	*****	******	*****	****	9,20	20.0	8.6
8	21	75	1	930000.	930000.	890000.	290000.	7,35	20,31	12,65	*****	15,51	14,17	****	7,59	16.5	4.6
8	21	75	2	2300.	2300.	2200.	540.					******	*****	****	8,12	19.5	4.0
8	21	75	3	400.	300.	1.	81.					******	*****	****	8,32	19.5	7.6
8	21	75	4	150.	30.	0.	28.					******	*****	****	8,90	20.0	7.3
8	21	75	5	1200.	30.	0.	31.					******	*****	****	9,32	20.0	15.4
8	21	75	6	4300.	93.	0.	180.					******	*****	****	8,70	20.0	11.0
8	21	75	7	930.	30.	0.	180.					******	*****	****	8,85	19.0	1.0
8	21	75	8	150.	23.	13.	24.					******	*****	****	8,32	19.5	7.2

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L
8	21	75	9	4300.	4.	0.	5.	******	******	*****	*****	******	*****	****	8.90	20.0	7.5
8	26	75	1	430000.	75000.	520000.	12.	9.49	19.63	5.00	0.94	7.00	8.31	****	7.87	16.0	4.7
8	26	75	2	4300.	750.	550.	150.					******	*****	****	8.57	19.5	7.4
8	26	75	3	9300.	230.	37.	99.					******	*****	****	8.00	19.5	5.2
8	26	75	4	210.	9.	34.	11.					******	*****	****	8.90	19.5	9.2
8	26	75	5	15000.	40.	61.	21.					******	*****	****	9.42	19.0	13.4
8	26	75	6	280.	3.	27.	0.					******	*****	****	9.31	19.5	11.3
8	26	75	7	430.	23.	21.	15.					******	*****	****	9.03	18.5	0.3
8	26	75	8	11000.	9.	17.	26.					******	*****	****	9.00	18.5	9.4
8	26	75	9	1500.	30.	31.	16.	******	******	*****	*****	******	*****	****	9.02	18.5	8.0
8	28	75	1	930000.	93000.	62.	8.	7.52	42.08	8.90	0.21	11.97	13.54	****	****	16.5	4.7
8	28	75	2	2300.	230.	430.	67.					******	*****	****	8.62	19.0	11.8
8	28	75	3	930.	40.	91.	45.					******	*****	****	8.22	19.0	4.7
8	28	75	4	210.	30.	2.	50.					******	*****	****	8.89	19.5	9.8
8	28	75	5	110.	30.	46.	46.					******	*****	****	9.35	19.5	6.0
8	28	75	6	2300.	40.	46.	59.					******	*****	****	9.29	19.5	11.2
8	28	75	7	75.	20.	24.	150.					******	*****	****	9.00	19.0	0.5
8	28	75	9	4300.	40.	9.	10.	******	******	*****	*****	******	*****	****	8.98	19.0	5.5
9	2	75	1	930000.	430000.	30.	150000.	4.23	96.36	8.83	0.49	5.48	6.10	****	****	15.0	5.6
9	2	75	2	640.	90.	0.	100.					******	*****	****	8.87	18.0	11.1
9	2	75	3	9300.	750.	0.	740.					******	*****	****	8.30	18.0	1.5
9	2	75	4	40.	30.	0.	37.					******	*****	****	8.80	18.0	3.3
9	2	75	5	750.	90.	0.	11.					******	*****	****	9.26	18.0	8.8
9	2	75	6	930.	30.	0.	0.					******	*****	****	9.30	18.0	8.2
9	2	75	7	93.	15.	0.	10.					******	*****	****	****	18.0	0.6
9	2	75	8	2400.	23.	0.	34.					******	*****	****	9.27	18.0	6.9
9	2	75	9	7500.	90.	0.	21.	******	******	*****	*****	******	*****	****	9.23	18.0	7.0
9	4	75	1	230000.	230000.	460000.	80000.	6.11	71.52	5.88	0.52	6.28	7.72	****	8.05	16.0	5.1
9	4	75	2	930.	70.	220.	93.					******	*****	****	8.83	19.0	15.4
9	4	75	3	3900.	930.	570.	180.					******	*****	****	8.15	19.0	1.4
9	4	75	4	40.	40.	53.	15.					******	*****	****	8.62	19.0	1.6
9	4	75	5	280.	30.	73.	15.					******	*****	****	9.24	19.0	11.4
9	4	75	6	390.	40.	33.	7.					******	*****	****	9.20	19.0	13.0
9	4	75	7	28.	15.	0.	4.					******	*****	****	9.22	19.0	9.8
9	4	75	8	2400.	15.	40.	14.					******	*****	****	9.10	18.5	10.2
9	4	75	9	2300.	30.	50.	10.	******	******	*****	*****	******	*****	****	9.16	19.0	9.0
9	9	75	1	750000.	75000.	540000.	150000.	4.82	20.49	8.58	0.44	6.24	7.06	****	7.73	16.0	5.0
9	9	75	2	230.	230.	280.	60.					******	*****	****	8.60	19.0	6.5
9	9	75	3	2300.	40.	390.	96.					******	*****	****	8.17	19.0	1.9
9	9	75	4	150.	23.	20.	41.					******	*****	****	8.50	19.0	2.2
9	9	75	5	930.	230.	33.	83.					******	*****	****	9.20	19.0	10.8
9	9	75	6	930.	30.	67.	8.					******	*****	****	9.28	19.0	10.8
9	9	75	7	43.	4.	20.	5.					******	*****	****	9.28	18.0	1.0
9	9	75	8	4600.	4.	0.	6.					******	*****	****	9.43	18.0	7.7
9	9	75	9	640.	30.	0.	1.	******	******	*****	*****	******	*****	****	9.45	18.0	8.3
9	16	75	1	93000.	23000.	640000.	87000.	8.06	24.52	9.05	0.50	6.56	7.40	****	8.98	****	****
9	16	75	2	1500.	430.	340.	124.					******	*****	****	8.17	****	****
9	16	75	3	24000.	230.	590.	100.					******	*****	****	8.59	****	****

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L
9	16	75	4	930.	75.	55.	20.					******	*****	****	8,40	****	****
9	16	75	5	210.	30.	35.	6.					******	*****	****	9,10	****	****
9	16	75	6	1200.	40.	78.	11.					******	*****	****	9,10	****	****
9	16	75	7	430.	9.	8.	8.					******	*****	****	9,32	****	****
9	16	75	8	430.	4.	32.	5.					******	*****	****	9,34	****	****
9	16	75	9	930.	30.	16.	2.	******	******	*****	*****	******	*****	****	9,37	****	****
9	18	75	1	930000.	930000.	680000.	150000.	13,28	26,97	7,45	0,56	11,26	9,80	****	8,97	16,0	5,3
9	18	75	2	4300.	2300.	780.	410.					******	*****	****	8,09	17,5	4,1
9	18	75	3	43000.	230.	250.	31.					******	*****	****	8,79	17,5	14,2
9	18	75	4	93.	43.	8.	17.					******	*****	****	8,35	18,0	2,4
9	18	75	5	1500.	30.	80.	10.					******	*****	****	9,18	18,0	10,8
9	18	75	6	1200.	40.	60.	10.					******	*****	****	9,00	18,0	16,3
9	18	75	7	2400.	15.	40.	9.					******	*****	****	9,13	17,0	17,4
9	18	75	8	210.	23.	4.	0.					******	*****	****	9,20	17,0	12,7
9	18	75	9	930.	30.	0.	5.	******	******	*****	*****	******	*****	****	9,27	19,0	14,3
9	23	75	1	2400000.	430000.	1200000.	530000.	13,28	32,98	7,62	0,79	10,60	9,00	****	7,91	15,0	5,5
9	23	75	2	430.	430.	33.	96.					******	*****	****	8,03	16,0	2,3
9	23	75	3	39000.	4300.	820.	0.					******	*****	****	9,15	15,0	2,0
9	23	75	4	230.	93.	8.	49.					******	*****	****	8,22	16,0	1,0
9	23	75	5	90.	40.	18.	14.					******	*****	****	9,22	16,0	10,2
9	23	75	6	1500.	30.	13.	1.					******	*****	****	9,00	16,0	8,8
9	23	75	7	23.	4.	0.	1.					******	*****	****	8,92	16,0	1,6
9	23	75	8	21.	9.	0.	6.					******	*****	****	9,08	16,0	3,9
9	23	75	9	230.	30.	6.	0.	******	******	*****	*****	******	*****	****	9,10	16,0	4,8
9	25	75	1	430000.	93000.	590000.	130000.	12,52	38,96	7,87	0,69	8,85	8,16	****	8,00	15,0	4,7
9	25	75	2	12000.	750.	810.	700.					******	*****	****	8,03	16,0	1,6
9	25	75	3	240000.	9300.	710.	0.					******	*****	****	9,10	16,0	15,7
9	25	75	4	230.	93.	100.	110.					******	*****	****	9,15	16,0	0,4
9	25	75	5	210.	40.	84.	12.					******	*****	****	9,28	16,0	12,8
9	25	75	6	210.	30.	0.	1.					******	*****	****	8,90	16,0	8,8
9	25	75	7	43.	4.	4.	0.					******	*****	****	8,82	15,0	0,8
9	25	75	8	750.	9.	3.	0.					******	*****	****	9,01	16,0	3,1
9	25	75	9	150.	30.	1.	5.	******	******	*****	*****	******	*****	****	8,92	16,0	4,3
9	30	75	1	1500000.	430000.	630000.	210000.	11,04	13,96	3,82	0,94	7,12	6,12	****	7,92	16,0	4,9
9	30	75	2	24000.	24000.	610.	3300.					******	*****	****	7,80	16,0	2,0
9	30	75	3	43000.	90.	770.	740.					******	*****	****	8,85	16,0	8,7
9	30	75	4	4600.	230.	8.	260.					******	*****	****	7,86	16,0	1,3
9	30	75	5	930.	30.	40.	0.					******	*****	****	9,10	16,0	8,2
9	30	75	6	930.	30.	8.	5.					******	*****	****	8,61	16,0	3,2
9	30	75	7	2400.	90.	40.	13.					******	*****	****	8,64	15,0	4,2
9	30	75	8	430.	23.	24.	4.					******	*****	****	8,80	16,0	5,1
9	30	75	9	930.	30.	9.	5.	******	******	*****	*****	******	*****	****	8,75	16,0	2,9
10	2	75	1	1500000.	150000.	730000.	130000.	******	******	*****	*****	******	*****	****	****	****	****
10	2	75	2	24000.	430.	3900.	870.					******	*****	****	****	****	****
10	2	75	3	2300.	2300.	700.	96.					******	*****	****	****	****	****
10	2	75	4	2400.	230.	170.	130.					******	*****	****	****	****	****
10	2	75	5	90.	30.	48.	3.					******	*****	****	****	****	****
10	2	75	6	750.	30.	18.	3.					******	*****	****	****	****	****

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L
10	2	75	7	93.	4.	12.	3.					******	*****	****	****	****	****
10	2	75	9	430.	30.	9.	2.	******	******	*****	*****	******	*****	****	****	****	****
10	7	75	1	4600000.	750000.	0.	300000.	11,84	32,63	10,65	3,76	12,58	9,84	****	8,10	16,0	4,7
10	7	75	2	110000.	9300.	3500.	0.					******	*****	****	7,90	16,0	1,2
10	7	75	3	1100000.	75000.	740.	0.					******	*****	****	7,62	16,0	0,8
10	7	75	4	24000.	2400.	130.	0.					******	*****	****	****	16,0	10,6
10	7	75	5	2300.	210.	100.	72.					******	*****	****	8,58	16,0	4,2
10	7	75	6	46000.	930.	6.	0.					******	*****	****	8,39	16,0	4,1
10	7	75	7	2400.	9.	160.	10.					******	*****	****	8,21	16,0	1,8
10	7	75	8	230.	3.	24.	0.					******	*****	****	8,45	16,0	2,4
10	7	75	9	390.	30.	14.	0.	******	******	*****	*****	******	*****	****	8,37	16,0	2,1
10	9	75	1	230000.	93000.	710000.	140000.	9,23	6,69	4,41	1,41	5,90	5,70	****	8,00	15,5	5,3
10	9	75	2	24000.	9300.	9300.	1900.					******	*****	****	8,00	12,0	2,8
10	9	75	3	24000.	4300.	3700.	770.					******	*****	****	8,10	12,0	2,0
10	9	75	4	24000.	430.	310.	330.					******	*****	****	8,60	12,0	12,0
10	9	75	5	90.	30.	32.	12.					******	*****	****	8,50	13,0	4,0
10	9	75	6	930.	40.	32.	0.					******	*****	****	8,40	13,0	4,4
10	9	75	7	93.	43.	24.	13.					******	*****	****	8,20	13,0	1,5
10	9	75	8	230.	3.	4.	6.					******	*****	****	8,00	13,5	2,2
10	9	75	9	930.	30.	0.	4.	******	******	*****	*****	******	*****	****	8,40	13,5	2,4
10	14	75	1	1100000.	230000.	840000.	210000.	******	17,39	51,87	1,55	13,52	9,44	****	7,90	16,0	5,6
10	14	75	2	13000.	3300.	150000.	2700.					******	*****	****	8,52	11,0	16,8
10	14	75	3	1300.	130.	730.	93.					******	*****	****	7,98	11,0	3,3
10	14	75	4	2400.	230.	940.	340.					******	*****	****	8,50	12,0	9,5
10	14	75	5	40.	20.	16.	4.					******	*****	****	8,09	12,0	3,0
10	14	75	6	140.	20.	8.	0.					******	*****	****	8,11	12,0	3,8
10	14	75	7	22.	22.	24.	1.					******	*****	****	8,00	12,0	1,8
10	14	75	8	79.	4.	16.	0.					******	*****	****	7,98	12,0	1,3
10	14	75	9	490.	20.	10.	2.	******	******	*****	*****	******	*****	****	8,02	12,0	1,3
10	21	75	1	1100000.	460000.	550000.	63000.	15,25	7,96	5,21	1,30	11,64	11,04	6,0	7,90	15,0	5,1
10	21	75	2	160000.	1700.	13000.	1000.					******	*****	****	8,60	13,0	13,3
10	21	75	3	1100.	20.	670.	27.					******	*****	****	8,00	13,0	2,0
10	21	75	4	9200.	70.	1400.	47.					******	*****	****	8,80	13,0	12,0
10	21	75	5	20.	20.	20.	2.					******	*****	****	8,10	12,0	2,2
10	21	75	6	210.	20.	20.	2.					******	*****	****	8,20	12,0	3,0
10	21	75	7	180.	8.	12.	7.					******	*****	****	8,20	11,0	2,8
10	21	75	8	350.	13.	0.	4.					******	*****	****	8,10	11,0	1,4
10	21	75	9	90.	20.	0.	1.	******	******	*****	*****	******	*****	****	8,10	12,0	1,3
10	23	75	1	5400000.	350000.	780000.	35000.	10,49	36,11	15,62	1,38	7,80	8,04	****	****	15,5	5,9
10	23	75	2	92000.	1700.	85000.	5200.					******	*****	****	8,40	10,5	10,3
10	23	75	3	70000.	3500.	5800.	530.					******	*****	****	7,99	10,5	3,0
10	23	75	4	24000.	220.	2400.	125.					******	*****	****	8,81	10,0	14,5
10	23	75	5	1100.	170.	210.	88.					******	*****	****	7,97	10,5	4,4
10	23	75	6	7000.	1700.	180.	6.					******	*****	****	8,25	10,5	4,8
10	23	75	7	1800.	220.	56.	28.					******	*****	****	8,07	10,5	2,0
10	23	75	8	350.	46.	3.	2.					******	*****	****	7,91	10,5	2,5
10	23	75	9	1800.	170.	0.	3.	******	******	*****	*****	******	*****	****	8,05	10,5	2,6
10	28	75	1	3500000.	490000.	100000.	76000.	******	******	*****	*****	******	*****	****	****	****	****

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C°	DO MG/L
10	28	75	2	92000.	17000.	42000.	2800.					******	*****	****	****	****	****
10	28	75	3	33000.	4900.	8400.	790.					******	*****	****	****	****	****
10	28	75	4	5400.	33.	1700.	15.					******	*****	****	****	****	****
10	28	75	5	220.	110.	100.	26.					******	*****	****	****	****	****
10	28	75	6	4900.	80.	120.	58.					******	*****	****	****	****	****
10	28	75	7	46.	31.	24.	9.					******	*****	****	****	****	****
10	28	75	8	180.	14.	0.	2.					******	*****	****	****	****	****
10	28	75	9	1300.	20.	0.	0.	******	******	*****	*****	******	*****	****	****	****	****
10	30	75	1	2400000.	230000.	600000.	18000.	13.07	39.74	18.82	2.38	7.80	6.17	****	****	14.5	5.6
10	30	75	2	54000.	17000.	26000.	3000.					******	*****	****	8.63	7.0	13.8
10	30	75	3	49000.	2800.	5300.	580.					******	*****	****	8.00	7.0	4.3
10	30	75	4	5400.	700.	3300.	0.					******	*****	****	8.90	7.0	13.3
10	30	75	5	330.	330.	110.	52.					******	*****	****	8.10	7.0	6.6
10	30	75	6	490.	20.	72.	21.					******	*****	****	8.42	7.0	10.0
10	30	75	7	14.	33.	12.	6.					******	*****	****	8.07	7.0	3.8
10	30	75	8	23.	23.	4.	0.					******	*****	****	8.05	7.5	3.8
10	30	75	9	20.	20.	0.	0.	******	******	*****	*****	******	*****	****	7.99	7.5	3.7
11	4	75	1	1300000.	330000.	100000.	92000.	8.35	15.99	6.12	2.21	10.82	9.28	4.5	2.00	13.0	6.1
11	4	75	2	54000.	3500.	32000.	3600.					******	*****	****	8.83	8.0	20.0
11	4	75	3	2800.	700.	2000.	40.					******	*****	****	8.00	8.0	5.9
11	4	75	4	3500.	170.	1700.	190.					******	*****	****	9.12	8.0	19.8
11	4	75	5	80.	20.	24.	2.					******	*****	****	8.08	8.0	6.8
11	4	75	6	210.	70.	56.	18.					******	*****	****	8.58	8.0	10.6
11	4	75	7	330.	9.	4.	4.					******	*****	****	8.02	8.0	4.6
11	4	75	8	280.	8.	2.	1.					******	*****	****	8.06	8.0	2.6
11	4	75	9	330.	20.	0.	0.	******	******	*****	*****	******	*****	****	8.10	8.0	3.1
11	6	75	1	1300000.	790000.	1000000.	46000.	14.52	23.72	21.63	2.07	10.64	9.32	****	8.30	8.0	****
11	6	75	2	35000.	17000.	37000.	3000.					******	*****	****	8.90	8.0	****
11	6	75	3	210.	20.	130.	0.					******	*****	****	8.00	8.0	****
11	6	75	4	1700.	490.	2000.	210.					******	*****	****	9.15	8.0	****
11	6	75	5	20.	20.	8.	0.					******	*****	****	8.17	8.0	****
11	6	75	6	80.	20.	52.	5.					******	*****	****	8.65	8.0	****
11	6	75	7	5.	0.	16.	1.					******	*****	****	8.02	7.5	****
11	6	75	8	13.	5.	0.	1.					******	*****	****	8.12	7.5	****
11	6	75	9	50.	20.	0.	1.	******	******	*****	*****	******	*****	****	7.98	7.5	****
11	11	75	1	1700000.	330000.	1700000.	200000.	2.25	63.81	21.01	13.56	15.28	13.46	5.5	8.09	13.0	5.4
11	11	75	2	54000.	54000.	83000.	16000.					******	*****	****	8.70	6.0	9.9
11	11	75	3	220000.	49000.	0.	0.					******	*****	****	8.00	6.0	5.4
11	11	75	4	790.	49.	1500.	50.					******	*****	****	9.20	5.0	15.0
11	11	75	5	3300.	790.	0.	0.					******	*****	****	8.16	6.0	6.5
11	11	75	6	900.	20.	36.	64.					******	*****	****	8.22	6.0	10.4
11	11	75	7	460.	110.	56.	26.					******	*****	****	8.15	6.0	5.3
11	11	75	8	330.	8.	4.	1.					******	*****	****	8.16	6.0	5.1
11	11	75	9	90.	20.	0.	1.	******	******	*****	*****	******	*****	****	8.06	6.0	5.3
11	13	75	1	5400000.	1100000.	810000.	110000.	12.72	24.84	10.16	1.93	17.67	12.92	****	7.81	14.0	6.0
11	13	75	2	92000.	92000.	37000.	4200.					******	*****	****	8.68	5.0	12.4
11	13	75	3	79000.	4600.	13000.	600.					******	*****	****	8.02	5.0	4.1
11	13	75	4	2400.	70.	950.	50.					******	*****	****	9.22	4.5	16.8

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L
11	13	75	5	2200.	490.	540.	120.					******	*****	****	8.18	5.0	6.6
11	13	75	6	1300.	230.	140.	80.					******	*****	****	8.82	5.0	11.5
11	13	75	7	14.	8.	12.	9.					******	*****	****	8.08	5.5	5.1
11	13	75	8	11.	0.	0.	2.					******	*****	****	8.12	5.5	4.9
11	13	75	9	22.	8.	0.	0.	******	******	*****	*****	******	*****	****	8.10	6.0	4.8
11	18	75	1	1300000.	490000.	920000.	88000.	7.28	20.17	20.79	8.74	20.40	6.78	****	7.82	11.0	5.3
11	18	75	2	11000.	7000.	20000.	2300.					******	*****	****	8.80	6.0	15.8
11	18	75	3	4900.	330.	3500.	200.					******	*****	****	8.03	6.0	6.4
11	18	75	4	27.	17.	130.	0.					******	*****	****	9.27	5.0	18.2
11	18	75	5	1100.	40.	68.	20.					******	*****	****	8.20	5.0	7.2
11	18	75	6	430.	20.	28.	4.					******	*****	****	8.79	5.0	11.8
11	18	75	7	220.	13.	24.	9.					******	*****	****	8.51	5.0	8.4
11	18	75	8	79.	2.	3.	2.					******	*****	****	8.23	5.0	5.9
11	18	75	9	490.	5.	7.	0.	******	******	*****	*****	******	*****	****	8.19	5.0	6.5
11	20	75	1	790000.	230000.	1400000.	1200000.	******	******	*****	*****	******	*****	****	7.91	13.5	7.7
11	20	75	2	35000.	24000.	21000.	2900.					******	*****	****	8.82	4.5	9.5
11	20	75	3	1100.	70.	690.	6.					******	*****	****	8.20	4.5	5.5
11	20	75	4	1100.	230.	870.	410.					******	*****	****	9.20	4.0	17.4
11	20	75	5	90.	20.	3.	0.					******	*****	****	8.30	4.0	8.9
11	20	75	7	11.	5.	10.	2.					******	*****	****	3.51	4.0	6.8
11	20	75	8	13.	8.	3.	3.					******	*****	****	8.33	4.0	8.8
11	20	75	9	17.	0.	3.	1.	******	******	*****	*****	******	*****	****	8.25	4.5	9.3
11	25	75	1	22000000.	11000000.	2900000.	0.	61.20	148.79	44.74	10.79	68.15	52.25	****	7.70	13.0	5.3
11	25	75	2	240000.	160000.	100000.	0.					******	*****	****	8.52	6.0	10.4
11	25	75	3	17000.	2300.	8000.	0.					******	*****	****	8.12	4.0	9.7
11	25	75	4	2400.	490.	900.	420.					******	*****	****	9.18	3.0	17.0
11	25	75	5	20.	20.	12.	0.					******	*****	****	8.23	5.0	8.2
11	25	75	6	90.	20.	24.	2.					******	*****	****	9.08	4.0	14.2
11	25	75	7	3500.	79.	52.	36.					******	*****	****	8.70	3.0	11.8
11	25	75	8	790.	5.	15.	10.					******	*****	****	8.46	3.0	11.8
11	25	75	9	350.	13.	30.	7.	******	******	*****	*****	******	*****	****	8.51	3.0	12.2
12	2	75	1	54000000.	1700000.	2700000.	780000.	57.10	71.00	48.21	6.90	71.10	52.35	29.3	7.65	13.0	4.9
12	2	75	2	160000.	92000.	73000.	0.					******	*****	****	8.35	4.0	12.4
12	2	75	3	79000.	11000.	9000.	1800.					******	*****	****	7.97	4.0	9.5
12	2	75	4	4900.	2300.	2200.	0.					******	*****	****	9.03	4.0	15.2
12	2	75	5	1400.	79.	140.	20.					******	*****	****	8.30	5.0	8.2
12	2	75	6	230.	23.	12.	4.					******	*****	****	8.89	5.0	10.2
12	2	75	7	790.	0.	4.	2.					******	*****	****	8.90	5.0	13.0
12	2	75	8	230.	4.	0.	1.					******	*****	****	8.78	4.0	10.6
12	2	75	9	790.	0.	10.	0.	******	******	*****	*****	******	*****	****	8.78	4.0	10.5
12	4	75	1	17000000.	2200000.	7200000.	720000.	72.30	163.12	67.61	9.22	67.46	46.64	10.0	7.60	14.0	3.0
12	4	75	2	22000.	3300.	15000.	270.					******	*****	****	****	4.5	11.5
12	4	75	3	1700.	1100.	530.	33.					******	*****	****	****	5.5	7.8
12	4	75	4	1300.	220.	360.	47.					******	*****	****	****	4.5	15.3
12	4	75	5	330.	23.	12.	2.					******	*****	****	****	5.0	7.6
12	4	75	6	110.	13.	36.	6.					******	*****	****	****	4.5	13.3
12	4	75	7	17.	4.	0.	0.					******	*****	****	****	5.0	8.2
12	4	75	8	7.	0.	2.	0.					******	*****	****	****	4.5	8.8

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L
12	4	75	9	8.	0.	2.	0.	******	******	*****	*****	******	*****	****	****	4.5	8.5
12	9	75	1	7900000.	7900000.	3800000.	900000.	68.00	174.27	51.30	9.76	66.68	49.52	23.0	8.05	13.0	3.3
12	9	75	2	35000.	4900.	10000.	270.					******	*****	****	8.52	6.0	13.2
12	9	75	3	35000.	2200.	8000.	730.					******	*****	****	8.27	6.0	9.3
12	9	75	4	79.	5.	20.	0.					******	*****	****	8.90	5.0	16.7
12	9	75	5	230.	8.	12.	2.					******	*****	****	8.62	5.5	11.6
12	9	75	6	23.	0.	4.	3.					******	*****	****	8.63	5.0	11.2
12	9	75	7	2.	0.	4.	0.					******	*****	****	8.51	5.0	7.0
12	9	75	8	17.	0.	0.	0.					******	*****	****	8.70	5.0	7.9
12	9	75	9	9.	2.	1.	0.	3.62	23.16	19.24	2.07	4.84	6.48	4.6	8.64	6.0	7.1
12	11	75	1	9400000.	2200000.	2100000.	740000.	199.00	63.04	30.24	5.61	36.12	32.20	****	8.55	13.5	3.1
12	11	75	2	24000.	13000.	6300.	1100.					******	*****	****	****	6.0	11.0
12	11	75	3	1400.	270.	400.	33.					******	*****	****	****	6.0	18.5
12	11	75	4	49.	17.	5.	0.					******	*****	****	****	6.0	15.6
12	11	75	5	490.	17.	28.	5.					******	*****	****	****	5.5	15.5
12	11	75	6	33.	5.	4.	0.					******	*****	****	****	5.5	12.8
12	11	75	7	23.	9.	2.	0.					******	*****	****	****	5.5	3.3
12	11	75	8	79.	6.	0.	0.					******	*****	****	****	5.5	3.8
12	11	75	9	220.	9.	2.	0.	******	******	*****	*****	******	*****	****	****	5.5	4.1
12	16	75	1	14000000.	3500000.	1900000.	420000.	******	******	*****	*****	******	*****	****	7.72	12.0	****
12	16	75	2	18000.	1800.	670.	60.					******	*****	****	8.20	12.0	****
12	16	75	3	3500.	1400.	2200.	270.					******	*****	****	8.90	12.0	****
12	16	75	4	700.	26.	20.	5.					******	*****	****	8.68	12.0	****
12	16	75	5	16000.	17.	51.	1.					******	*****	****	8.63	12.0	****
12	16	75	6	790.	17.	4.	0.					******	*****	****	8.26	12.0	****
12	16	75	7	46.	2.	3.	0.					******	*****	****	8.30	12.0	****
12	16	75	8	26.	6.	0.	0.					******	*****	****	8.37	12.0	****
12	16	75	9	790.	270.	0.	0.	******	******	*****	*****	******	*****	****	8.40	12.0	****
12	18	75	1	24000000.	240000.	0.	0.	******	******	*****	5.18	221.00	91.18	****	7.95	12.0	****
12	18	75	2	17000.	13000.	4800.	260.					******	*****	****	8.05	4.0	****
12	18	75	3	940.	94.	200.	6.					******	*****	****	8.92	4.0	****
12	18	75	4	350.	94.	35.	90.					******	*****	****	8.66	3.0	****
12	18	75	5	460.	34.	8.	1.					******	*****	****	8.88	3.0	****
12	18	75	6	70.	63.	0.	2.					******	*****	****	8.06	3.0	****
12	18	75	7	13.	17.	0.	0.					******	*****	****	8.32	3.0	****
12	18	75	8	43.	8.	0.	0.					******	*****	****	8.35	3.0	****
12	18	75	9	34.	17.	0.	0.	******	******	*****	*****	******	*****	****	8.32	3.0	****
12	31	75	1	3300000.	800000.	0.	29000.	******	******	*****	*****	******	*****	10.0	8.00	11.5	7.3
12	31	75	2	240000.	240000.	0.	0.					******	*****	****	7.90	4.5	3.9
12	31	75	3	35000.	11000.	88.	0.					******	*****	****	8.70	4.0	11.2
12	31	75	4	16000.	3500.	0.	0.					******	*****	****	8.10	4.0	2.8
12	31	75	5	9.	4.	0.	0.					******	*****	****	8.90	4.0	8.1
12	31	75	6	110.	110.	79.	0.					******	*****	****	8.50	4.0	3.0
12	31	75	7	2.	0.	1.	0.					******	*****	****	8.40	4.0	2.7
12	31	75	8	5.	5.	1.	1.					******	*****	****	8.30	5.0	3.0
12	31	75	9	0.	0.	1.	0.	******	******	*****	*****	******	*****	****	8.30	5.0	3.1
1	2	76	1	700000.	700000.	0.	290000.	25.00	******	*****	*****	******	*****	****	7.97	11.0	8.0
1	2	76	2	1600000.	540000.	0.	0.					******	*****	****	7.81	4.0	3.5

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C°	DO MG/L
1	2	76	3	4600.	3100.	0.	420.					******	*****	****	8.91	4.0	11.1
1	2	76	4	24000.	24000.	0.	0.					******	*****	****	8.00	4.0	3.1
1	2	76	5	17.	22.	0.	0.					******	*****	****	8.91	4.0	8.5
1	2	76	6	310.	110.	0.	150.					******	*****	****	8.30	3.5	2.8
1	2	76	7	5.	2.	0.	0.					******	*****	****	8.30	3.5	3.1
1	2	76	8	2.	0.	0.	4.					******	*****	****	8.27	4.0	3.3
1	2	76	9	11.	0.	0.	2.	******	******	*****	*****	******	*****	****	8.36	3.5	3.3
1	6	76	1	3300000.	1700000.	1800000.	620000.	******	******	*****	*****	30.34	20.18	****	7.75	11.5	5.0
1	6	76	2	1300000.	1300000.	0.	120000.					******	*****	****	7.60	4.0	0.4
1	6	76	3	350000.	11000.	610.	0.					******	*****	****	8.20	4.0	3.4
1	6	76	4	240000.	160000.	0.	0.					******	*****	****	7.74	3.5	0.3
1	6	76	5	490.	70.	80.	0.					******	*****	****	8.70	3.5	12.3
1	6	76	6	1300.	280.	140.	0.					******	*****	****	8.27	3.0	1.3
1	6	76	7	23.	8.	0.	3.					******	*****	****	8.22	3.0	0.9
1	6	76	8	13.	0.	0.	3.					******	*****	****	8.20	4.0	0.4
1	6	76	9	8.	5.	0.	0.	******	******	*****	*****	******	*****	****	8.19	4.0	0.6
1	6	76	1	790000.	330000.	0.	0.	25.40	56.95	41.09	19.45	8.36	8.56	6.9	7.75	4.0	5.7
1	8	76	1	22000000.	22000000.	3800000.	2200000.	42.10	152.24	46.08	11.50	99.00	76.20	45.0	8.20	12.0	3.4
1	8	76	2	940000.	490000.	500000.	160000.					******	*****	****	7.84	5.0	1.5
1	8	76	3	220000.	79000.	4200.	2400.					******	*****	****	8.22	5.0	2.8
1	8	76	4	240000.	240000.	0.	0.					******	*****	****	7.95	4.0	2.2
1	8	76	5	350.	110.	100.	10.					******	*****	****	8.75	4.0	10.0
1	8	76	6	16000.	16000.	0.	0.					******	*****	****	8.42	4.0	2.7
1	8	76	7	0.	0.	12.	2.					******	*****	****	8.29	3.0	2.6
1	8	76	8	0.	0.	1.	1.					******	*****	****	8.21	3.0	2.0
1	8	76	9	31.	17.	3.	1.	******	******	*****	*****	******	*****	****	8.29	3.0	2.0
1	13	76	1	17000000.	4600000.	5400000.	2200000.	68.60	150.44	30.50	11.14	73.87	58.93	28.0	8.01	12.0	5.2
1	13	76	2	490000.	490000.	590000.	220000.					******	*****	7.7	7.75	5.0	3.9
1	13	76	3	130000.	33000.	0.	0.					******	*****	7.7	8.18	4.0	4.5
1	13	76	4	920000.	130000.	0.	0.					******	*****	5.8	7.82	5.0	3.6
1	13	76	5	46.	13.	27.	3.					******	*****	8.0	8.44	4.0	5.2
1	13	76	6	94.	140.	130.	12.					******	*****	4.1	8.31	3.0	2.8
1	13	76	7	63.	13.	3.	4.					******	*****	3.7	8.26	3.0	1.8
1	13	76	9	17.	8.	0.	4.	4.58	33.25	25.36	2.90	5.15	3.50	4.0	8.28	3.0	1.1
1	15	76	1	92000000.	0.	5500000.	1900000.	73.16	143.04	46.21	9.96	105.00	97.25	30.0	8.05	12.0	4.0
1	15	76	2	9200000.	0.	670000.	210000.					9.57	9.28	7.4	7.38	5.0	0.9
1	15	76	3	1600000.	0.	0.	0.					28.23	26.37	7.1	7.90	5.0	1.7
1	15	76	4	0.	0.	0.	0.					9.10	8.83	6.0	7.79	4.0	1.6
1	15	76	5	24000.	0.	370.	110.					35.71	32.46	6.3	8.36	3.5	6.1
1	15	76	6	0.	0.	10.	16.					13.58	14.33	6.7	8.25	2.0	1.4
1	15	76	7	0.	0.	5.	1.					6.72	10.25	4.0	8.25	3.0	1.8
1	15	76	8	0.	0.	17.	23.					4.75	9.92	4.1	8.26	2.0	1.5
1	15	76	9	0.	0.	3.	0.	3.04	34.13	30.48	2.88	1.40	5.20	3.5	8.21	6.0	2.9
1	20	76	1	22000000.	24000000.	6300000.	2300000.	74.81	155.58	73.13	11.47	65.03	61.31	36.0	7.99	12.0	3.9
1	20	76	2	1700000.	1100000.	510000.	180000.					10.82	*****	8.3	5.68	5.5	1.2
1	20	76	3	1600000.	920000.	410000.	58000.					51.54	*****	10.0	7.90	4.5	0.6
1	20	76	4	2400000.	2400000.	290000.	93000.					7.50	*****	6.5	7.73	3.5	****
1	20	76	5	17000.	17000.	0.	0.					22.44	*****	5.6	8.21	3.5	0.9

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C°	DO MG/L
1	20	76	6	180.	33.	0.	8.					23.21	*****	5.6	8.28	3.0	1.6
1	20	76	7	180.	23.	5.	2.					6.92	*****	4.3	8.12	3.0	1.1
1	20	76	8	350.	79.	8.	5.					7.28	*****	4.5	8.22	3.0	0.8
1	20	76	9	33.	33.	0.	0.	******	******	*****	*****	4.17	*****	3.6	8.27	3.0	2.1
1	22	76	1	92000000.	92000000.	5900000.	1200000.	111.00	241.30	85.40	19.24	607.00	*****	36.0	7.88	11.0	5.2
1	22	76	2	5400000.	5400000.	530000.	150000.					12.00	12.00	11.0	7.68	4.0	2.0
1	22	76	3	2800000.	1800000.	130000.	30000.					31.68	31.68	8.5	8.01	4.0	1.4
1	22	76	4	3500000.	3500000.	240000.	40000.					7.46	7.46	7.0	7.20	4.0	1.0
1	22	76	5	35000.	0.	1400.	710.					17.18	17.18	5.5	8.12	4.0	1.3
1	22	76	6	350.	350.	7.	4.					32.50	32.50	6.3	8.42	2.0	2.1
1	22	76	7	180.	180.	16.	1.					6.61	6.61	5.0	8.24	2.0	1.8
1	22	76	8	350.	350.	16.	15.					12.24	12.24	4.6	8.29	3.0	1.3
1	22	76	9	180.	180.	1.	1.	3.42	25.44	25.40	13.42	9.60	9.60	3.5	8.28	3.0	2.6
1	27	76	1	3300000.	1300000.	2400000.	1100000.	61.00	81.78	50.93	8.28	51.80	43.37	20.0	7.95	11.0	3.9
1	27	76	2	4600000.	790000.	670000.	280000.					12.20	*****	20.0	7.60	4.0	0.4
1	27	76	3	790000.	490000.	280000.	66000.					39.50	*****	10.0	7.85	3.5	0.5
1	27	76	4	1100000.	230000.	210000.	72000.					11.02	*****	10.0	7.72	3.0	0.5
1	27	76	5	54000.	54000.	0.	0.					13.27	*****	5.5	7.98	3.0	0.5
1	27	76	6	23.	7.	3.	0.					34.22	*****	6.1	8.18	2.0	0.6
1	27	76	7	140.	2.	0.	3.					8.72	*****	5.8	8.12	1.5	0.9
1	27	76	8	2300.	17.	14.	12.					7.71	*****	5.2	8.12	3.5	0.3
1	27	76	9	14.	2.	2.	3.	3.98	34.64	26.35	3.03	24.20	*****	4.5	8.20	3.5	0.3
1	29	76	1	11000000.	4600000.	4800000.	2000000.	122.00	351.93	55.37	9.91	72.60	67.20	36.0	7.91	11.0	3.6
1	29	76	2	4900000.	1100000.	610000.	220000.					14.44	14.44	29.0	7.48	4.0	0.5
1	29	76	3	1300000.	230000.	130000.	51000.					28.75	28.75	8.4	7.89	3.0	0.4
1	29	76	4	1700000.	1100000.	180000.	93000.					8.91	8.91	11.0	7.68	3.0	0.8
1	29	76	5	35000.	24000.	0.	0.					14.49	14.49	6.1	7.92	3.0	0.6
1	29	76	6	5.	2.	67.	0.					48.92	48.92	7.3	8.59	2.0	1.9
1	29	76	7	33.	2.	0.	0.					6.81	6.81	4.7	8.18	2.5	1.1
1	29	76	8	34.	8.	5.	3.					10.09	10.09	3.2	8.15	2.5	0.7
1	29	76	9	17.	2.	0.	3.	6.27	114.50	99.99	2.97	4.72	4.72	3.5	8.14	5.0	1.1
2	3	76	1	17000000.	11000000.	2400000.	840000.	320.00	321.95	*****	9.58	97.40	*****	80.0	7.82	9.5	1.0
2	3	76	2	7900000.	700000.	660000.	280000.					20.46	*****	22.0	7.56	2.0	1.1
2	3	76	3	1300000.	330000.	290000.	86000.					28.26	*****	8.8	7.80	3.0	0.2
2	3	76	4	700000.	700000.	270000.	53000.					1.50	*****	15.0	7.63	2.0	0.5
2	3	76	5	35000.	13000.	7700.	3000.					9.90	*****	6.5	7.92	1.5	0.4
2	3	76	6	8.	0.	20.	0.					28.59	*****	4.7	8.45	0.5	6.5
2	3	76	7	17.	0.	4.	0.					7.60	*****	3.6	8.13	1.0	0.5
2	3	76	8	46.	2.	6.	4.					8.06	*****	4.6	8.09	1.0	0.4
2	3	76	9	17.	0.	1.	0.	8.82	26.89	23.96	3.12	2.56	*****	3.1	8.15	3.5	0.7
2	5	76	1	4600000.	4600000.	6800000.	1900000.	126.00	131.13	62.41	14.52	109.00	*****	47.0	8.08	12.0	2.4
2	5	76	2	2300000.	490000.	670000.	210000.					******	*****	20.0	7.70	3.0	0.7
2	5	76	3	700000.	330000.	230000.	58000.					26.72	*****	12.0	7.88	3.0	0.5
2	5	76	4	490000.	490000.	190000.	58000.					7.44	*****	15.0	7.84	3.0	0.9
2	5	76	5	33000.	13000.	14000.	3000.					14.06	*****	5.7	8.06	2.5	1.0
2	5	76	6	8.	2.	10.	0.					32.20	*****	7.3	8.76	2.0	7.8
2	5	76	7	17.	0.	12.	1.					******	*****	5.1	8.30	3.0	1.6
2	5	76	8	23.	2.	4.	0.					******	*****	5.0	8.28	3.5	1.1

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L
2	5	76	9	33.	0.	2.	5.	3.74	24.30	24.07	2.75	7.16	*****	4.4	8.28	2.0	0.8
2	10	76	1	3300000.	2300000.	4300000.	870000.	105.00	216.40	84.26	11.70	85.00	74.00	47.0	8.10	10.0	4.2
2	10	76	2	1300000.	790000.	630000.	170000.					******	*****	27.0	7.59	3.5	0.5
2	10	76	3	490000.	230000.	200000.	40000.					******	*****	10.0	7.82	3.0	0.6
2	10	76	4	330000.	330000.	280000.	55000.					******	*****	22.0	7.63	3.0	0.4
2	10	76	5	79000.	49000.	12000.	3100.					******	*****	6.2	7.85	2.5	0.5
2	10	76	6	7.	2.	0.	3.					******	*****	6.4	8.73	2.0	0.2
2	10	76	7	0.	0.	8.	0.					******	*****	3.7	8.23	2.0	0.4
2	10	76	8	11.	5.	0.	1.					******	*****	5.1	8.12	2.0	0.4
2	10	76	9	2.	2.	1.	2.	5.41	28.16	25.36	3.30	******	13.50	3.6	8.10	2.0	0.3
2	12	76	1	4900000.	3300000.	3300000.	910000.	76.60	176.35	43.91	7.69	76.67	*****	25.0	8.00	11.0	3.2
2	12	76	2	1300000.	1300000.	620000.	170000.					10.83	*****	26.0	7.48	3.0	0.9
2	12	76	3	790000.	330000.	250000.	69000.					19.69	*****	15.0	7.70	2.5	0.8
2	12	76	4	790000.	790000.	280000.	60000.					18.86	*****	22.0	7.60	3.0	0.7
2	12	76	5	350000.	350000.	39000.	9000.					76.11	*****	6.9	7.80	3.0	0.9
2	12	76	6	11.	2.	0.	0.					10.32	*****	8.1	8.68	2.0	7.8
2	12	76	7	5.	0.	4.	0.					6.89	*****	5.5	8.12	2.0	1.1
2	12	76	8	23.	17.	2.	0.					1.63	*****	4.9	8.15	3.0	1.0
2	12	76	9	33.	17.	2.	0.	4.52	28.29	22.40	3.03	2.80	*****	4.1	8.11	3.0	1.0
2	17	76	1	700000.	1700000.	2500000.	450000.	30.30	71.46	22.87	4.59	1.72	1.04	10.0	8.03	10.0	4.9
2	17	76	2	1300000.	790000.	670000.	200000.					2.25	1.33	20.0	7.61	3.5	0.9
2	17	76	3	330000.	130000.	150000.	41000.					4.48	2.81	8.2	7.92	3.5	0.6
2	17	76	4	490000.	490000.	240000.	58000.					0.62	0.35	22.0	7.67	3.0	0.5
2	17	76	5	110000.	70000.	55000.	8500.					26.26	*****	8.5	7.85	3.0	0.5
2	17	76	6	23.	0.	0.	0.					6.49	5.82	6.6	8.22	2.5	0.4
2	17	76	7	8.	0.	2.	1.					4.21	0.37	4.0	8.17	2.0	0.7
2	17	76	8	5.	0.	0.	1.					0.51	*****	4.2	8.17	2.0	0.4
2	17	76	9	5.	0.	2.	1.	5.18	29.85	24.38	3.17	0.36	0.08	4.2	8.13	2.5	0.5
2	19	76	1	3000000.	2800000.	3600000.	1300000.	70.00	166.13	47.04	9.86	103.00	86.60	35.0	7.80	10.0	4.2
2	19	76	2	1700000.	1100000.	1000000.	170000.					16.07	15.16	20.0	7.39	2.0	0.6
2	19	76	3	1400000.	490000.	370000.	110000.					14.77	12.77	11.0	7.60	1.0	0.9
2	19	76	4	1300000.	790000.	340000.	50000.					11.60	11.60	17.0	7.50	1.0	0.6
2	19	76	5	110000.	46000.	73000.	6400.					17.05	17.05	7.5	7.90	1.0	1.0
2	19	76	6	130.	33.	67.	18.					42.56	38.43	7.2	8.40	1.0	2.5
2	19	76	7	12.	49.	0.	0.					4.88	4.66	5.6	8.20	1.0	0.9
2	19	76	8	79.	7.	0.	0.					14.68	13.60	3.5	8.50	1.0	1.1
2	19	76	9	46.	8.	1.	0.	4.67	30.70	21.96	3.40	4.60	4.28	4.0	8.10	1.0	1.2
2	24	76	1	35000000.	3300000.	0.	5100000.	81.70	124.81	56.81	9.70	80.40	62.50	31.0	7.56	10.0	6.0
2	24	76	2	1300000.	790000.	1000000.	160000.					16.18	14.27	30.0	7.20	4.0	0.3
2	24	76	3	1300000.	790000.	510000.	100000.					13.05	13.05	20.0	7.28	3.5	0.5
2	24	76	4	1700000.	460000.	450000.	110000.					11.67	11.49	25.0	7.20	3.0	0.5
2	24	76	5	330000.	170000.	130000.	10000.					11.16	10.89	9.0	7.48	3.0	0.4
2	24	76	6	24000.	24000.	0.	0.					12.27	12.27	12.0	7.48	2.5	0.6
2	24	76	7	70.	49.	26.	20.					4.23	4.23	8.5	7.77	2.5	0.4
2	24	76	8	110.	46.	0.	39.					22.66	22.55	4.2	8.07	2.5	0.4
2	24	76	9	1100.	700.	0.	0.	7.50	39.70	27.66	3.54	4.72	4.56	5.2	7.30	2.5	0.5
2	26	76	1	3300000.	2300000.	6700000.	1500000.	91.00	200.58	58.30	7.44	73.00	61.67	30.0	8.13	11.0	2.9
2	26	76	2	790000.	790000.	860000.	240000.					15.65	14.76	22.0	7.65	3.0	0.6

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C°	DO MG/L
2	26	76	3	790000.	220000.	620000.	110000.					12.50	12.50	15.0	7.82	2.0	0.3
2	26	76	4	2200000.	1300000.	440000.	120000.					12.22	12.22	23.0	7.71	2.0	0.5
2	26	76	5	330000.	170000.	100000.	25000.					14.60	14.60	14.0	8.05	1.0	0.6
2	26	76	6	240000.	160000.	0.	0.					18.92	15.92	14.0	8.10	1.0	0.5
2	26	76	7	24000.	24000.	0.	0.					5.00	5.00	7.7	8.07	1.5	0.6
2	26	76	8	790.	790.	0.	0.					8.66	8.66	5.3	8.21	1.0	0.5
2	26	76	9	16000.	9200.	0.	0.	8.35	3.53	26.56	4.68	4.08	3.60	8.5	8.08	2.0	0.5
3	2	76	1	490000.	490000.	2100000.	870000.	46.90	96.30	25.30	2.65	41.64	24.20	12.0	8.18	11.0	7.3
3	2	76	2	3300000.	490000.	1100000.	240000.					22.93	28.94	32.0	7.87	3.0	0.7
3	2	76	3	490000.	490000.	560000.	140000.					12.35	11.82	21.0	7.99	3.0	0.8
3	2	76	4	2300000.	330000.	260000.	150000.					13.56	14.07	39.0	8.00	2.0	0.9
3	2	76	5	490000.	130000.	170000.	67000.					8.07	8.00	17.0	8.32	2.0	0.8
3	2	76	6	350000.	130000.	0.	0.					10.57	10.51	19.0	8.21	2.0	0.8
3	2	76	7	49000.	13000.	0.	0.					9.11	7.81	13.0	8.23	2.0	0.8
3	2	76	8	24000.	24000.	0.	0.					6.58	6.80	11.0	8.40	2.0	1.3
3	2	76	9	54000.	7900.	6700.	0.	10.63	42.10	24.80	4.71	5.68	5.24	12.0	8.18	2.0	0.9
3	4	76	1	22000000.	3500000.	3300000.	1300000.	68.10	126.42	35.71	7.49	94.00	68.40	43.0	8.14	10.0	4.0
3	4	76	2	1300000.	330000.	810000.	230000.					19.43	18.21	28.0	7.83	4.0	0.2
3	4	76	3	1100000.	460000.	470000.	170000.					13.50	1.13	30.0	8.03	3.5	0.3
3	4	76	4	1300000.	230000.	380000.	140000.					17.86	15.24	39.0	7.96	3.0	0.3
3	4	76	5	3300000.	330000.	210000.	65000.					10.95	9.91	20.0	8.22	2.5	0.2
3	4	76	6	230000.	230000.	0.	0.					10.09	10.57	23.0	8.13	2.0	0.4
3	4	76	7	110000.	46000.	0.	0.					16.00	2.40	18.0	8.21	2.0	0.3
3	4	76	8	17000.	17000.	0.	0.					13.35	11.57	11.0	8.33	2.5	0.2
3	4	76	9	23000.	7900.	7500.	0.	9.79	28.28	18.62	4.79	8.40	8.90	16.0	8.20	2.5	0.5
3	9	76	1	3300000.	3300000.	1300000.	470000.	36.54	128.11	24.23	7.55	73.30	46.90	25.0	7.95	9.0	7.9
3	9	76	2	330000.	170000.	960000.	240000.					21.72	22.04	16.0	7.54	4.0	0.5
3	9	76	3	2300000.	1300000.	480000.	210000.					15.26	14.42	28.0	7.53	3.0	0.6
3	9	76	4	460000.	170000.	350000.	100000.					19.40	17.18	36.0	7.53	3.0	0.3
3	9	76	5	280000.	220000.	260000.	81000.					12.85	11.90	14.0	7.70	2.0	0.4
3	9	76	6	490000.	220000.	160000.	63000.					13.11	13.11	23.0	7.69	2.0	0.3
3	9	76	7	350000.	170000.	88000.	0.					11.31	10.90	11.0	7.69	2.0	0.3
3	9	76	8	110000.	79000.	33000.	24000.					11.39	11.69	8.6	7.73	2.0	0.2
3	9	76	9	23000.	23000.	45000.	21000.	13.15	45.75	30.09	7.27	7.56	7.88	9.7	8.78	2.0	0.5
3	11	76	1	8000000.	7000000.	6100000.	2100000.	80.00	******	49.72	7.65	74.51	54.51	30.0	7.90	10.0	7.2
3	11	76	2	2300000.	490000.	1100000.	260000.					23.47	23.16	22.0	7.88	4.5	0.3
3	11	76	3	35000000.	3500000.	710000.	250000.					14.70	15.00	45.0	7.79	4.0	0.4
3	11	76	4	940000.	940000.	470000.	99000.					18.90	18.40	52.0	8.06	3.0	0.3
3	11	76	5	310000.	310000.	210000.	80000.					13.00	11.80	28.0	8.10	2.5	0.4
3	11	76	6	330000.	230000.	210000.	65000.					14.50	13.70	33.0	8.13	2.5	0.3
3	11	76	7	170000.	170000.	78000.	36000.					12.90	13.00	18.0	8.19	2.0	0.4
3	11	76	8	49000.	49000.	52000.	21000.					11.50	10.90	17.0	8.32	2.0	0.2
3	11	76	9	110000.	110000.	50000.	22000.	15.23	43.50	29.05	6.19	21.00	21.80	22.0	8.30	2.0	0.3
3	16	76	1	790000.	330000.	1700000.	430000.	67.60	42.20	33.74	9.50	61.25	33.13	14.0	7.83	10.0	6.6
3	16	76	2	1300000.	490000.	750000.	170000.					25.70	23.13	23.0	7.58	4.5	0.3
3	16	76	3	490000.	230000.	480000.	120000.					15.78	12.81	38.0	7.50	4.0	0.6
3	16	76	4	700000.	170000.	310000.	79000.					20.44	17.72	46.0	7.52	3.5	0.6
3	16	76	5	170000.	170000.	260000.	76000.					14.61	11.48	25.0	7.68	3.0	0.4

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L
3	16	76	6	330000.	330000.	190000.	67000.					15.47	13.50	32.0	7.65	3.0	0.6
3	16	76	7	170000.	79000.	84000.	28000.					17.81	14.56	18.0	7.65	2.0	0.4
3	16	76	8	110000.	70000.	46000.	23000.					15.52	13.51	17.0	7.70	2.0	0.4
3	16	76	9	130000.	4900.	60000.	27000.	14.85	51.02	33.15	7.05	13.41	8.62	17.0	7.70	2.0	0.3
3	18	76	1	4900000.	4900000.	3100000.	870000.	55.00	83.51	27.28	4.01	43.00	32.92	20.0	7.90	10.0	6.2
3	18	76	2	460000.	230000.	710000.	180000.					29.67	25.49	23.0	7.70	5.0	0.9
3	18	76	3	1300000.	330000.	500000.	160000.					18.49	14.13	43.0	7.63	3.0	0.5
3	18	76	4	330000.	330000.	320000.	140000.					22.36	18.76	53.0	7.75	4.0	0.4
3	18	76	5	220000.	220000.	210000.	75000.					13.05	9.92	37.0	7.75	3.0	0.4
3	18	76	6	330000.	280000.	170000.	59000.					15.29	13.17	41.0	7.71	2.0	0.3
3	18	76	7	79000.	79000.	80000.	30000.					16.61	13.23	28.0	7.72	2.5	0.4
3	18	76	8	130000.	33000.	47000.	25000.					19.73	16.43	32.0	7.82	2.0	0.5
3	18	76	9	70000.	46000.	67000.	17000.	18.50	50.51	27.89	7.11	13.60	11.48	22.0	7.70	2.0	0.4
3	23	76	1	790000.	490000.	740000.	220000.	48.30	138.99	25.25	4.47	34.75	26.45	25.0	7.90	10.0	6.2
3	23	76	2	490000.	230000.	520000.	65000.					31.50	28.75	15.0	7.77	5.0	1.4
3	23	76	3	790000.	790000.	390000.	120000.					16.16	15.52	29.0	7.61	4.0	1.4
3	23	76	4	790000.	790000.	230000.	49000.					27.22	26.48	22.0	7.68	4.0	1.5
3	23	76	5	790000.	490000.	210000.	53000.					11.88	11.40	33.0	7.69	3.0	1.5
3	23	76	6	140000.	140000.	200000.	31000.					19.62	19.19	36.0	7.68	3.0	5.8
3	23	76	7	330000.	79000.	71000.	22000.					15.12	14.64	25.0	7.67	3.0	1.0
3	23	76	8	33000.	33000.	32000.	6300.					31.20	29.44	11.0	8.03	2.0	0.9
3	23	76	9	110000.	46000.	53000.	13000.	18.45	42.59	22.60	6.54	19.80	18.84	15.0	7.65	3.0	0.9
3	25	76	1	700000.	170000.	800000.	510000.	26.30	94.81	26.03	4.61	97.65	39.65	43.0	7.86	9.5	6.9
3	25	76	2	700000.	110000.	280000.	13000.					25.80	23.14	12.0	7.52	4.0	1.2
3	25	76	3	490000.	170000.	200000.	20000.					35.89	33.02	10.0	7.94	4.0	1.6
3	25	76	4	170000.	50000.	110000.	17000.					23.41	20.87	11.0	7.80	3.5	1.4
3	25	76	5	280000.	170000.	180000.	45000.					31.25	29.13	15.0	7.73	3.5	4.7
3	25	76	6	230000.	130000.	90000.	25000.					22.84	21.17	33.0	7.62	2.5	3.6
3	25	76	7	170000.	49000.	42000.	15000.					20.40	18.55	16.0	7.56	3.0	0.8
3	25	76	8	33000.	23000.	30000.	6000.					26.65	17.20	11.0	7.75	2.5	0.7
3	25	76	9	330000.	49000.	38000.	9000.	18.00	53.78	16.88	7.91	22.80	12.72	12.0	7.83	2.5	1.0
3	30	76	1	1700000.	490000.	700000.	140000.	64.70	223.12	38.56	5.38	56.30	44.10	18.0	7.80	9.0	6.7
3	30	76	2	110000.	20000.	100000.	4000.					26.54	23.85	8.0	7.87	5.0	6.7
3	30	76	3	230000.	20000.	77000.	2700.					19.20	17.20	6.0	7.95	5.0	4.5
3	30	76	4	490000.	80000.	150000.	17000.					33.62	29.08	11.0	7.80	4.5	3.2
3	30	76	5	70000.	33000.	93000.	30000.					44.88	40.92	7.8	8.61	3.0	0.9
3	30	76	6	140000.	94000.	140000.	32000.					22.72	20.44	18.0	7.82	3.0	2.5
3	30	76	7	130000.	33000.	76000.	27000.					19.04	17.92	16.0	7.69	3.0	1.1
3	30	76	8	410000.	110000.	38000.	14000.					20.64	18.60	13.0	7.79	2.0	1.2
3	30	76	9	140000.	94000.	49000.	17000.	16.75	57.57	26.69	8.29	19.57	18.28	10.0	7.70	3.0	0.4
4	1	76	1	1700000.	1700000.	1500000.	740000.	43.53	13.48	32.96	5.78	65.71	50.65	28.0	7.82	10.0	7.0
4	1	76	2	17000.	8000.	33000.	2000.					19.46	19.46	11.0	8.62	9.0	14.4
4	1	76	3	20000.	2000.	22000.	1300.					54.53	52.07	12.0	8.60	5.5	10.0
4	1	76	4	20000.	20000.	34000.	2000.					26.75	26.00	12.0	8.02	4.0	6.7
4	1	76	5	130000.	130000.	45000.	2600.					44.93	43.47	10.0	8.91	4.0	7.4
4	1	76	6	230000.	130000.	92000.	15000.					23.93	23.93	12.0	7.98	4.5	6.5
4	1	76	7	170000.	70000.	50000.	10000.					75.00	70.90	15.0	8.72	3.5	1.6
4	1	76	8	79000.	49000.	34000.	4900.					37.73	35.23	2.4	7.92	3.0	1.5

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C°	DO MG/L
4	1	76	9	79000.	33000.	36000.	9800.	18.23	58.43	22.85	6.96	25.62	24.79	10.0	7.79	3.0	1.8
4	6	76	1	790000.	230000.	1000000.	300000.	******	160.76	41.33	5.14	55.23	35.40	21.0	7.87	10.0	6.2
4	6	76	2	33000.	11000.	29000.	4200.					33.40	32.40	7.1	8.80	10.0	11.3
4	6	76	3	33000.	33000.	63000.	14000.					20.36	20.88	9.2	8.61	9.5	9.2
4	6	76	4	7000.	1700.	10000.	2000.					32.47	30.07	9.6	8.92	5.5	11.0
4	6	76	5	6000.	2000.	10000.	530.					21.64	21.52	4.2	9.32	5.0	9.9
4	6	76	6	1700.	4000.	21000.	1800.					29.65	21.80	8.2	8.05	5.0	5.4
4	6	76	7	1300.	2000.	24000.	400.					35.93	35.14	7.6	7.80	5.0	1.6
4	6	76	8	5000.	2000.	8000.	200.					53.67	50.67	7.2	8.00	4.5	1.1
4	6	76	9	2100.	2000.	10000.	300.	******	70.57	19.25	6.88	36.13	34.33	6.4	8.56	5.0	1.2
4	8	76	1	700000.	490000.	1200000.	470000.	4.55	92.55	25.52	3.99	44.36	33.80	19.0	8.00	9.5	7.2
4	8	76	2	17000.	3300.	28000.	3100.					47.20	42.73	13.0	9.12	11.5	11.8
4	8	76	3	240000.	3300.	72000.	15000.					27.65	24.70	18.0	8.20	10.0	0.5
4	8	76	4	4900.	200.	3100.	400.					33.27	31.47	13.0	8.91	5.0	5.2
4	8	76	5	800.	200.	0.	0.					72.47	58.20	16.0	9.20	6.0	5.8
4	8	76	6	4900.	500.	3600.	100.					27.10	24.40	8.0	8.28	6.0	8.2
4	8	76	7	2700.	200.	3300.	0.					46.33	43.33	12.0	8.22	5.0	8.5
4	8	76	8	2700.	200.	3400.	200.					42.73	40.40	11.0	8.60	5.0	6.8
4	8	76	9	2300.	200.	6200.	0.	23.53	79.01	20.87	4.04	36.89	39.02	6.6	8.03	5.0	7.0
4	13	76	1	940000.	490000.	1500000.	550000.	66.10	158.71	27.37	5.08	63.59	49.77	17.0	7.78	10.0	6.4
4	13	76	2	350000.	33000.	57000.	9100.					45.38	43.38	12.0	8.85	13.0	10.6
4	13	76	3	130000.	79000.	89000.	19000.					29.11	26.96	8.5	7.98	12.0	0.9
4	13	76	4	13000.	790.	6000.	570.					32.11	29.55	8.3	8.83	11.0	9.6
4	13	76	5	5400.	3500.	16000.	630.					20.19	20.19	7.3	7.91	10.0	0.9
4	13	76	6	170.	20.	1400.	33.					38.93	20.60	7.6	8.29	10.5	5.1
4	13	76	7	140.	20.	670.	0.					24.93	22.43	9.4	8.20	10.0	5.6
4	13	76	8	790.	20.	1500.	0.					36.21	34.85	8.2	8.51	10.0	10.1
4	13	76	9	330.	20.	1500.	0.	23.10	82.12	24.07	3.52	33.36	31.82	8.3	8.48	10.0	9.7
4	15	76	1	1300000.	1300000.	2200000.	940000.	87.60	290.22	59.15	6.83	79.00	62.95	4.1	7.90	10.0	5.9
4	15	76	2	140000.	33000.	110000.	18000.					47.50	45.10	9.2	8.98	12.0	10.2
4	15	76	3	130000.	13000.	58000.	1600.					28.80	27.90	7.2	8.31	12.0	5.0
4	15	76	4	17000.	460.	10000.	630.					37.93	35.40	11.0	8.96	11.0	9.4
4	15	76	5	790.	170.	15000.	130.					22.95	20.75	6.7	8.20	12.0	4.4
4	15	76	6	330.	130.	1500.	68.					26.30	23.30	9.6	8.61	12.0	6.7
4	15	76	7	170.	20.	500.	16.					18.80	15.88	8.1	7.99	10.0	1.0
4	15	76	8	20.	20.	270.	0.					13.88	12.68	5.4	8.10	10.0	1.7
4	15	76	9	70.	20.	370.	0.	12.38	49.58	20.60	3.47	16.85	15.65	6.2	8.00	10.0	1.4
4	20	76	1	2200000.	5400000.	1800000.	710000.	60.07	64.67	34.49	6.11	74.87	57.13	27.0	7.42	10.5	6.2
4	20	76	2	7900.	700.	2500.	320.					4.80	4.38	11.0	8.18	11.5	20.0
4	20	76	3	1300.	500.	8300.	400.					43.67	40.33	8.0	8.10	10.5	20.0
4	20	76	4	790.	80.	1700.	145.					28.30	25.70	8.8	8.13	11.0	17.2
4	20	76	5	1200.	20.	1100.	10.					38.75	32.00	13.0	8.07	11.0	20.0
4	20	76	6	1100.	20.	440.	13.					28.73	25.20	10.0	7.97	11.0	15.2
4	20	76	7	79.	0.	150.	3.					24.55	19.55	10.0	7.70	10.0	7.4
4	20	76	8	26.	0.	100.	3.					19.65	18.05	8.3	7.62	10.0	7.3
4	20	76	9	17.	0.	76.	2.	9.80	48.22	21.72	4.13	19.90	17.15	6.4	7.60	10.0	6.5
4	22	76	1	490000.	330000.	980000.	380000.	38.00	142.58	37.60	5.62	71.13	55.73	20.0	8.12	11.0	5.9
4	22	76	2	22000.	3300.	11000.	1300.					17.29	18.60	5.2	9.10	13.0	15.3

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C	DO MG/L
4	22	76	3	24000.	3300.	14000.	5700.					41.00	37.60	9.4	9.05	11.0	16.7
4	22	76	4	790.	330.	1300.	272.					26.68	18.32	8.1	9.21	12.0	17.0
4	22	76	5	330.	20.	200.	12.					21.34	17.84	9.8	8.99	12.0	17.7
4	22	76	6	50.	20.	60.	8.					32.31	26.21	7.3	8.92	12.0	14.3
4	22	76	7	170.	5.	88.	6.					20.60	16.85	7.7	8.62	12.0	9.5
4	22	76	8	140.	0.	20.	4.					21.00	17.40	7.0	8.59	12.0	9.1
4	22	76	9	180.	2.	25.	0.	7.97	48.34	29.69	1.85	19.48	17.96	7.3	8.66	12.0	9.2
4	27	76	1	1300000.	1300000.	1100000.	490000.	1.48	35.28	16.67	2.36	13.80	12.64	4.6	7.76	10.5	6.4
4	27	76	2	110000.	9400.	17000.	6600.					24.92	23.40	5.8	8.50	10.0	5.4
4	27	76	3	28000.	4600.	11000.	950.					38.29	37.43	8.4	9.11	10.0	15.8
4	27	76	4	790.	330.	830.	420.					18.40	5.08	4.5	9.15	10.0	13.2
4	27	76	5	140.	20.	170.	12.					5.04	4.60	8.5	9.25	10.0	15.6
4	27	76	6	220.	50.	45.	8.					19.24	17.20	5.2	9.07	10.0	13.6
4	27	76	7	33.	2.	25.	2.					14.52	13.92	3.2	8.75	10.0	10.2
4	27	76	8	33.	7.	18.	6.					15.92	14.84	4.2	8.71	10.0	11.9
4	27	76	9	110.	21.	25.	4.	7.88	39.78	19.54	2.28	15.56	14.76	3.0	8.73	10.0	11.6
4	29	76	1	490000.	330000.	770000.	170000.	66.60	67.55	32.42	4.78	76.64	65.36	36.0	8.05	10.5	7.3
4	29	76	2	11000.	3300.	11000.	1600.					27.24	25.28	8.1	8.90	12.5	10.7
4	29	76	3	23000.	13000.	14000.	2300.					40.20	38.90	9.3	9.48	12.5	20.9
4	29	76	4	1100.	80.	130.	24.					24.84	21.72	8.7	9.47	12.5	20.6
4	29	76	5	130.	17.	150.	8.					56.00	43.70	15.0	9.70	11.5	21.2
4	29	76	6	110.	13.	13.	8.					21.12	19.96	7.4	9.39	12.0	18.9
4	29	76	7	22.	0.	7.	2.					20.24	18.00	6.3	9.22	12.5	16.2
4	29	76	8	49.	2.	96.	3.					18.72	17.24	6.7	9.20	12.5	18.2
4	29	76	9	130.	0.	11.	2.	10.06	41.12	15.01	0.92	18.16	16.72	5.3	9.17	13.0	17.6
5	4	76	1	790000.	230000.	1300000.	490000.	70.50	188.24	53.38	5.04	160.00	81.30	43.0	7.80	11.0	6.3
5	4	76	2	4900.	500.	8900.	380.					40.80	33.53	13.0	8.27	18.0	23.0
5	4	76	3	70000.	33000.	30000.	9400.					36.80	30.35	11.0	8.17	14.0	12.4
5	4	76	4	4900.	80.	2500.	170.					51.40	38.25	18.0	8.32	14.5	18.7
5	4	76	5	220.	21.	230.	20.					27.20	23.10	10.0	8.40	14.0	18.9
5	4	76	6	49.	49.	45.	65.					29.76	21.96	14.0	8.35	15.0	17.7
5	4	76	7	63.	5.	28.	7.					34.48	24.00	15.0	8.30	16.0	15.5
5	4	76	8	79.	4.	11.	5.					24.72	19.52	12.0	****	15.0	18.2
5	4	76	9	79.	8.	9.	3.	13.80	41.92	18.86	0.34	22.40	18.53	7.4	8.15	15.0	17.5
5	6	76	1	24000000.	24000000.	1300000.	210000.	35.60	164.06	15.88	6.02	93.87	71.47	40.0	7.50	12.0	5.6
5	6	76	2	4900.	800.	9600.	640.					50.28	42.44	16.0	8.39	16.0	22.7
5	6	76	3	3300.	3300.	10000.	630.					20.24	19.96	9.5	8.04	16.5	20.5
5	6	76	4	130.	20.	130.	28.					32.52	27.04	11.0	8.58	16.0	21.8
5	6	76	5	170.	5.	170.	0.					12.80	9.24	4.3	8.62	15.5	16.4
5	6	76	6	33.	33.	20.	9.					21.80	21.80	8.2	8.07	16.0	19.5
5	6	76	7	13.	0.	10.	0.					19.96	15.88	7.8	8.32	15.5	15.0
5	6	76	8	2.	0.	9.	2.					21.88	17.88	8.6	8.46	15.5	18.0
5	6	76	9	11.	2.	4.	0.	8.34	42.29	12.63	0.10	20.16	17.04	8.1	8.50	15.5	17.5
5	11	76	1	3300000.	700000.	1200000.	270000.	56.90	******	35.01	7.28	62.75	47.20	35.0	8.43	12.0	5.8
5	11	76	2	130000.	9400.	34000.	3700.					39.02	32.68	15.0	9.52	17.5	17.4
5	11	76	3	7900.	1700.	8600.	810.					24.36	25.20	19.0	9.62	17.0	14.9
5	11	76	4	1700.	40.	500.	16.					15.20	12.04	8.7	9.78	17.5	14.5
5	11	76	5	140.	0.	150.	1.					8.92	6.84	3.3	9.90	17.0	10.9

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L
5	11	76	6	33.	4.	36.	7.					9.20	6.36	5.9	9.77	17.5	9.7
5	11	76	7	220.	0.	0.	0.					5.80	4.12	4.2	9.64	17.5	7.0
5	11	76	8	130.	0.	3.	0.					8.20	6.20	3.7	9.65	17.5	9.7
5	11	76	9	220.	0.	11.	0.	3.14	28.41	22.56	0.23	7.40	5.84	3.8	9.47	17.5	9.1
5	13	76	1	490000.	490000.	1300000.	110000.	57.10	183.14	35.98	6.11	74.13	59.80	23.0	8.00	12.0	5.6
5	13	76	2	170000.	79000.	51000.	10000.					35.07	28.53	22.0	9.34	16.5	11.2
5	13	76	3	200.	200.	270.	14.					34.35	24.70	29.0	9.58	16.0	13.4
5	13	76	4	790.	40.	880.	75.					16.32	9.16	17.0	9.60	16.5	8.8
5	13	76	5	170.	0.	20.	2.					8.32	5.84	4.3	9.81	17.0	10.2
5	13	76	6	63.	2.	12.	1.					7.72	3.88	8.6	9.57	17.0	5.4
5	13	76	7	26.	0.	3.	1.					5.76	3.52	4.1	9.40	17.0	2.8
5	13	76	8	170.	0.	15.	1.					4.92	3.64	3.8	9.42	16.5	5.0
5	13	76	9	180.	0.	3.	0.	5.01	25.06	24.24	0.56	7.48	6.24	3.6	9.40	16.5	4.5
5	18	76	1	4600000.	3100000.	1100000.	150000.	21.93	44.85	25.73	2.86	20.80	*****	6.0	8.81	11.5	5.7
5	18	76	2	330000.	14000.	110000.	34000.					23.36	*****	14.0	8.40	17.0	1.1
5	18	76	3	700.	140.	530.	130.					59.32	*****	22.0	9.81	19.0	18.2
5	18	76	4	1100.	90.	680.	30.					25.24	*****	13.0	8.80	19.5	1.1
5	18	76	5	33.	0.	40.	1.					6.92	*****	3.7	8.58	19.0	10.1
5	18	76	6	130.	27.	37.	9.					13.20	*****	8.0	8.20	18.5	0.5
5	18	76	7	46.	5.	8.	4.					31.32	*****	5.2	8.12	18.5	0.9
5	18	76	8	23.	0.	0.	3.					38.36	*****	3.0	8.10	19.0	0.9
5	18	76	9	79.	2.	4.	3.	9.60	50.35	16.88	1.40	4.76	*****	3.5	8.15	19.0	0.9
5	20	76	1	1700000.	1300000.	1000000.	220000.	41.73	88.48	21.48	3.00	58.44	39.76	20.0	7.85	11.5	6.5
5	20	76	2	23000.	2000.	44000.	2300.					48.33	41.53	18.0	8.15	19.0	1.2
5	20	76	3	92000.	4600.	5300.	0.					33.25	26.30	17.0	9.48	17.0	9.0
5	20	76	4	7000.	170.	410.	120.					38.03	22.35	29.0	8.82	19.0	1.4
5	20	76	5	33.	2.	20.	1.					12.12	8.16	5.4	9.14	19.0	10.6
5	20	76	6	110.	22.	43.	17.					13.44	5.92	11.0	8.14	19.5	1.9
5	20	76	7	220.	70.	3.	53.					7.72	3.56	5.7	9.10	13.5	1.5
5	20	76	8	3500.	8.	4.	5.					5.00	3.32	0.6	9.10	18.5	1.8
5	20	76	9	790.	13.	28.	5.	3.73	75.20	25.36	1.51	9.16	5.88	4.5	9.12	19.0	1.3
5	25	76	1	1300000.	1300000.	800000.	170000.	42.40	63.96	20.65	2.27	32.04	12.60	19.0	7.90	12.0	6.1
5	25	76	2	110000.	79000.	95000.	16000.					46.93	46.80	19.0	8.42	17.5	6.7
5	25	76	3	3300.	1400.	1800.	83.					28.80	17.27	9.4	9.59	17.0	11.1
5	25	76	4	3100.	700.	400.	87.					85.20	77.00	50.0	8.65	16.5	0.9
5	25	76	5	49.	23.	44.	1.					12.08	9.32	5.4	9.86	18.5	7.8
5	25	76	6	280.	46.	49.	3.					16.24	9.24	14.0	9.16	19.0	4.4
5	25	76	7	170.	94.	6.	6.					7.20	4.60	5.5	8.97	19.5	2.6
5	25	76	8	140.	13.	20.	3.					6.24	3.52	5.6	8.88	18.5	1.3
5	25	76	9	34.	17.	36.	12.	3.87	0.08	*****	1.80	6.80	4.76	5.4	8.87	18.5	1.4
5	27	76	1	290000.	110000.	790000.	110000.	22.47	79.21	15.48	3.25	27.12	22.16	13.0	7.84	12.0	7.1
5	27	76	2	49000.	2000.	19000.	2600.					28.56	22.60	20.0	9.00	19.0	19.6
5	27	76	3	1300.	200.	200.	25.					30.33	20.40	15.0	9.75	19.0	24.0
5	27	76	4	2100.	200.	460.	110.					7.64	5.32	2.7	8.85	19.0	7.4
5	27	76	5	430.	4.	36.	1.					16.52	11.72	6.0	9.71	19.0	11.6
5	27	76	6	280.	6.	49.	4.					9.04	5.76	12.0	9.10	19.0	7.1
5	27	76	7	70.	11.	26.	7.					5.48	3.80	8.0	8.90	18.5	4.0
5	27	76	8	110.	0.	2.	0.					6.96	4.76	7.0	8.80	19.0	2.6

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C	DO MG/L
5	27	76	9	79.	0.	1.	2.	6.05	27.30	23.89	2.59	8.28	5.00	6.1	8.80	19.0	2.6
6	1	76	1	2300000.	1300000.	1200000.	370000.	23.90	60.20	17.36	2.20	35.88	25.84	12.0	7.92	12.0	6.0
6	1	76	2	11000.	3300.	16000.	1500.					36.08	30.92	15.0	9.46	19.3	22.0
6	1	76	3	4900.	70.	1300.	47.					52.20	47.44	16.0	9.74	19.0	18.6
6	1	76	4	2300.	70.	320.	42.					20.92	16.68	18.0	8.66	19.0	1.4
6	1	76	5	13.	2.	4.	0.					18.36	15.40	6.5	9.80	20.0	14.1
6	1	76	6	17.	0.	43.	3.					13.84	6.52	8.4	9.18	20.5	6.0
6	1	76	7	1100.	17.	170.	5.					6.32	4.32	6.6	8.84	20.0	0.5
6	1	76	8	5.	0.	2.	0.					3.72	1.28	6.0	8.80	20.0	1.8
6	1	76	9	17.	2.	10.	5.	4.18	32.31	31.06	1.93	5.44	3.12	6.5	8.77	20.0	1.5
6	3	76	1	1300000.	490000.	670000.	40000.	25.1'	88.79	19.61	4.66	36.60	29.80	14.0	8.00	12.5	6.0
6	3	76	2	33000.	4600.	23000.	670.					42.36	38.44	13.0	9.43	20.0	22.0
6	3	76	3	940.	330.	1400.	65.					37.00	27.40	12.0	9.65	20.5	17.7
6	3	76	4	20.	20.	60.	0.					17.88	14.12	14.0	8.73	20.5	4.4
6	3	76	5	460.	7.	190.	2.					15.64	13.68	7.0	9.78	21.5	15.4
6	3	76	6	17.	0.	80.	0.					6.76	4.96	7.6	9.10	21.5	6.4
6	3	76	7	490.	8.	32.	7.					11.52	9.80	5.5	8.75	21.0	1.0
6	3	76	8	130.	0.	6.	1.					5.56	4.20	5.1	8.75	21.0	1.7
6	3	76	9	7.	0.	0.	0.	4.83	35.64	32.30	1.53	5.44	3.68	5.5	8.75	21.0	2.0
6	8	76	1	3500000.	1800000.	1300000.	210000.	24.97	87.26	18.58	1.83	39.95	30.20	10.0	8.08	13.5	5.1
6	8	76	2	500.	200.	588.	67.					24.70	19.35	17.0	9.03	20.5	7.5
6	8	76	3	330.	70.	150.	12.					30.95	27.30	11.0	9.72	21.0	20.6
6	8	76	4	260.	20.	43.	6.					36.76	39.68	10.0	8.42	21.5	0.7
6	8	76	5	27.	0.	0.	1.					24.04	18.96	10.0	9.70	22.0	14.4
6	8	76	6	350.	240.	0.	0.					6.60	6.20	6.2	9.10	22.0	6.9
6	8	76	7	17.	2.	20.	0.					5.04	4.16	5.0	8.76	21.5	1.3
6	8	76	8	33.	2.	0.	0.					9.60	7.92	5.5	8.72	21.0	1.5
6	8	76	9	23.	11.	13.	1.	2.75	32.13	31.75	1.85	7.12	5.64	4.7	8.72	21.0	1.0
6	10	76	1	24000000.	1800000.	840000.	230000.	******	52.97	15.68	1.18	23.44	19.03	14.0	7.79	12.0	6.3
6	10	76	2	3300.	460.	400.	0.					26.64	19.72	14.0	8.25	20.5	1.0
6	10	76	3	1300.	490.	1100.	88.					27.84	24.32	12.0	9.48	20.5	16.8
6	10	76	4	110.	20.	35.	4.					40.00	40.32	12.0	8.32	21.5	1.0
6	10	76	5	170.	4.	16.	2.					12.20	8.80	7.7	9.58	21.5	10.2
6	10	76	6	49.	2.	38.	1.					5.56	3.60	6.0	8.99	20.0	5.6
6	10	76	7	33.	2.	18.	2.					14.52	11.36	5.6	8.65	21.5	1.1
6	10	76	8	17.	0.	0.	1.					31.88	23.72	5.5	8.32	21.0	1.1
6	10	76	9	17.	7.	4.	6.	******	39.27	30.29	1.79	5.80	4.32	4.2	8.42	21.0	1.4
6	15	76	1	9200000.	460000.	530000.	120000.	******	53.87	13.17	0.34	34.92	29.20	8.3	7.85	15.3	6.6
6	15	76	2	13000.	2800.	6900.	1400.					21.84	19.76	8.7	8.22	16.2	6.3
6	15	76	3	2200.	130.	1200.	130.					22.88	20.24	7.8	9.15	15.3	4.0
6	15	76	4	13.	2.	60.	2.					10.56	8.04	8.2	8.24	16.3	1.4
6	15	76	5	17.	2.	16.	2.					5.04	2.48	5.7	9.39	17.0	7.2
6	15	76	6	11.	0.	8.	0.					8.44	5.40	6.9	8.55	17.4	1.3
6	15	76	7	4.	0.	6.	1.					3.36	2.24	6.3	8.42	17.0	1.1
6	15	76	8	11.	0.	0.	0.					5.92	4.00	5.7	8.34	17.0	1.4
6	15	76	9	2.	0.	0.	1.	******	41.30	29.18	2.36	7.16	4.68	6.3	8.29	17.0	1.3
6	17	76	1	16000000.	9200000.	1700000.	430000.	16.80	59.13	12.68	1.47	38.36	28.92	13.0	7.31	12.0	6.5
6	17	76	2	92000.	13000.	49000.	8400.					23.56	21.78	11.0	6.90	16.5	9.2

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP °C°	DO MG/L
6	17	76	3	5400.	50.	390.	34.					24.56	21.48	7.4	9.10	18.0	12.2
6	17	76	4	22.	2.	0.	3.					12.44	8.24	9.1	7.08	17.5	0.1
6	17	76	5	180.	2.	4.	2.					9.96	6.48	5.8	7.33	18.0	4.9
6	17	76	6	140.	0.	0.	0.					9.36	7.24	5.3	7.29	19.5	0.1
6	17	76	7	17.	0.	0.	0.					3.88	2.24	4.7	7.78	21.5	1.3
6	17	76	8	33.	0.	8.	0.					5.16	3.16	5.3	8.20	14.0	1.5
6	17	76	9	23.	0.	0.	0.	2.35	31.12	28.08	1.77	6.16	4.56	5.5	7.72	18.0	4.1
6	22	76	1	9200000.	2400000.	730000.	77000.	24.64	77.98	9.59	1.81	48.92	37.76	12.0	7.78	14.0	6.0
6	22	76	2	49000.	7000.	28000.	4200.					30.56	28.08	11.0	8.76	19.0	9.8
6	22	76	3	11000.	490.	0.	300.					23.24	21.16	7.4	9.22	21.0	14.6
6	22	76	4	33.	8.	0.	7.					11.60	7.40	10.0	8.16	21.5	1.7
6	22	76	5	350.	17.	200.	18.					10.24	9.32	4.6	9.11	21.5	6.2
6	22	76	6	700.	0.	24.	1.					13.48	9.20	5.8	8.38	21.0	1.1
6	22	76	7	31.	2.	0.	1.					4.60	3.36	5.2	8.32	21.0	1.4
6	22	76	8	23.	0.	10.	0.					3.60	2.72	3.8	8.28	21.0	1.3
6	22	76	9	33.	2.	0.	4.	3.14	37.11	30.53	1.39	10.84	8.04	4.4	8.18	21.0	0.9
6	24	76	1	3500000.	1700000.	600000.	70000.	19.28	87.32	17.98	0.25	30.92	23.36	12.0	0.78	12.0	6.3
6	24	76	2	22000.	7000.	20000.	4100.					26.32	23.00	13.0	8.76	19.0	7.0
6	24	76	3	170.	20.	100.	3.					11.12	10.04	3.8	9.02	19.0	4.0
6	24	76	4	70.	8.	0.	7.					24.08	15.56	16.0	8.23	19.0	1.0
6	24	76	5	220.	5.	44.	5.					9.84	1.04	5.6	9.52	20.0	7.2
6	24	76	6	70.	0.	20.	0.					14.04	10.44	7.7	8.38	19.5	1.0
6	24	76	7	17.	0.	0.	0.					12.32	8.12	7.6	8.28	20.0	0.8
6	24	76	8	17.	5.	7.	0.					10.88	9.08	6.1	8.28	20.0	0.8
6	24	76	9	23.	0.	0.	3.	2.83	35.67	33.52	1.11	7.36	7.36	5.5	8.20	20.0	1.9
6	29	76	1	330000.	330000.	640000.	1300000.	******	47.21	18.20	1.78	15.00	12.88	12.0	7.80	15.0	5.6
6	29	76	2	7900.	800.	4800.	250.					48.84	40.88	10.0	7.98	22.0	0.9
6	29	76	3	3300.	20.	1100.	7.					4.16	4.76	3.8	8.46	22.0	1.4
6	29	76	4	70.	5.	50.	1.					52.24	44.84	13.0	9.16	21.0	1.5
6	29	76	5	140.	13.	14.	2.					9.36	7.88	5.2	9.45	22.0	16.4
6	29	76	6	17.	7.	20.	3.					6.64	5.76	5.4	8.42	23.0	2.9
7	1	76	1	13000000.	330000.	500000.	60000.	24.20	39.16	11.93	1.62	37.20	32.72	10.0	7.72	15.0	6.2
7	1	76	2	17000.	800.	7600.	170.					12.24	10.88	9.4	8.00	21.0	6.0
7	1	76	3	3300.	230.	1000.	46.					4.48	5.00	3.2	8.40	21.5	4.6
7	1	76	4	1400.	13.	25.	10.					42.60	35.36	10.0	8.11	21.0	1.2
7	1	76	5	16000.	170.	0.	37.					21.72	17.84	10.0	9.25	22.0	8.9
7	6	76	1	5400000.	5400000.	670000.	120000.	9.98	50.45	16.12	0.68	60.48	42.12	4.3	7.82	15.0	6.5
7	6	76	2	34000.	1300.	0.	570.					99.90	92.33	23.0	8.33	23.0	6.6
7	6	76	3	9200.	110.	880.	72.					23.44	17.00	8.5	9.08	22.0	2.5
7	6	76	4	170.	17.	33.	8.					45.84	40.16	14.0	8.30	23.0	2.8
7	6	76	5	23.	23.	50.	15.					11.84	6.72	7.8	8.37	23.0	8.2
7	6	76	6	46.	13.	0.	5.					33.24	22.44	9.5	8.36	23.5	1.6
7	8	76	1	5400000.	2400000.	730000.	95000.	31.20	134.60	15.71	1.80	54.52	37.16	14.0	****	15.0	4.9
7	8	76	2	2300.	500.	1300.	60.					20.48	17.64	11.0	8.56	23.0	12.2
7	8	76	3	790.	20.	470.	18.					8.64	7.24	3.9	8.98	22.0	12.6
7	8	76	4	23.	2.	0.	9.					14.72	12.00	12.0	8.41	24.0	6.7
7	8	76	5	2400.	31.	1000.	0.					22.92	18.47	8.9	9.43	23.0	15.6
7	8	76	6	31.	0.	7.	2.					6.16	3.72	6.9	8.58	24.0	4.5

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L
7	13	76	1	2400000.	2400000.	810000.	300000.	22.10	53.32	10.05	1.95	35.46	24.46	10.0	7.99	15.3	6.2
7	13	76	2	13000.	13000.	14000.	0.					13.44	10.60	13.0	8.28	23.1	0.9
7	13	76	3	22000.	7000.	0.	0.					19.20	18.08	4.0	8.70	23.8	15.9
7	13	76	4	46.	7.	0.	14.					6.12	4.04	7.6	8.39	24.0	1.0
7	13	76	5	5400.	330.	940.	0.					23.88	20.40	7.8	9.41	24.8	16.0
7	13	76	6	1100.	170.	480.	0.					5.80	5.04	10.0	8.71	23.2	3.7
7	13	76	7	1400.	49.	860.	0.					15.36	11.64	6.2	8.50	25.0	2.0
7	13	76	8	280.	49.	400.	20.					16.00	10.80	4.2	8.52	24.9	0.7
7	13	76	9	3500.	790.	0.	0.	4.36	42.95	38.33	2.10	3.34	3.34	4.6	8.50	24.8	0.9
7	15	76	1	9200000.	3500000.	590000.	220000.	18.93	68.83	9.40	1.31	41.20	32.04	12.0	8.01	16.0	5.9
7	15	76	2	22000.	7000.	13000.	1700.					17.12	13.52	8.0	8.05	22.0	0.1
7	15	76	3	4900.	170.	230.	80.					11.68	9.92	4.9	8.78	23.5	19.3
7	15	76	4	330.	33.	33.	17.					13.52	10.81	7.8	8.03	23.5	0.1
7	15	76	5	1300.	240.	300.	180.					15.16	10.80	7.3	9.34	23.5	15.9
7	15	76	6	5400.	330.	113.	85.					7.28	4.32	6.5	8.81	23.5	4.4
7	15	76	7	5400.	70.	520.	98.					4.28	3.00	4.9	8.53	24.0	3.4
7	15	76	8	24000.	1100.	0.	0.					3.40	3.08	4.0	8.42	23.5	2.1
7	15	76	9	9200.	700.	2.	24.	2.92	72.18	38.56	3.01	5.00	4.32	3.8	8.40	24.5	1.7
7	20	76	1	330000.	170000.	360000.	40000.	20.85	30.06	27.62	1.62	24.36	22.48	10.0	7.83	16.0	6.4
7	20	76	2	1700.	200.	1600.	130.					18.40	*****	15.0	8.06	23.0	4.2
7	20	76	3	700.	70.	0.	0.					9.72	8.84	4.2	8.87	24.0	12.8
7	20	76	4	70.	0.	0.	6.					17.16	14.44	10.0	8.29	24.0	1.2
7	20	76	5	1100.	80.	0.	28.					11.24	8.72	7.8	9.38	24.5	16.0
7	20	76	6	50.	2.	25.	3.					14.56	9.48	10.0	8.73	24.0	3.8
7	20	76	7	920.	33.	100.	8.					6.88	5.28	5.2	8.99	25.0	9.5
7	20	76	8	490.	20.	0.	8.					15.08	10.72	6.0	8.05	24.0	2.1
7	20	76	9	2200.	20.	0.	8.	3.92	51.80	36.73	2.45	5.12	4.76	3.4	8.62	25.0	2.3
7	22	76	1	1300000.	230000.	1100000.	130000.	11.20	36.37	13.44	0.70	18.32	15.04	5.0	7.80	15.0	6.5
7	22	76	2	700.	400.	3800.	200.					20.76	15.80	15.0	8.18	24.0	5.3
7	22	76	3	54000.	1700.	0.	240.					15.64	14.52	5.5	8.81	24.0	14.6
7	22	76	4	220.	46.	0.	24.					16.76	12.04	12.0	8.18	24.0	1.5
7	22	76	5	940.	70.	67.	39.					11.52	9.56	7.5	9.28	24.5	10.9
7	22	76	6	330.	79.	100.	32.					11.72	4.08	6.2	8.87	23.0	4.9
7	22	76	7	490.	17.	0.	12.					11.44	11.44	5.7	8.75	24.0	6.6
7	22	76	8	490.	33.	50.	18.					5.92	5.40	4.5	8.67	24.0	3.7
7	22	76	9	1700.	230.	0.	0.	6.41	50.42	40.39	1.12	11.32	10.32	4.5	8.51	24.0	2.6
7	27	76	1	460000.	170000.	610000.	160000.	16.40	54.13	8.57	2.34	41.12	29.72	11.0	7.78	16.3	4.9
7	27	76	2	1700.	20.	200.	60.					23.24	21.48	16.0	8.72	23.0	14.6
7	27	76	3	170.	20.	0.	8.					4.40	4.16	3.6	8.96	24.6	7.7
7	27	76	4	170.	27.	100.	33.					21.40	13.88	14.0	8.22	24.6	3.2
7	27	76	5	940.	17.	5200.	11.					10.44	5.92	8.6	9.36	24.0	8.4
7	27	76	6	700.	130.	2300.	34.					10.92	6.48	8.3	9.36	24.0	9.5
7	27	76	7	49.	5.	800.	0.					10.28	7.56	5.6	9.10	23.0	8.4
7	27	76	8	490.	33.	780.	10.					9.52	7.84	3.7	9.02	24.0	5.8
7	27	76	9	170.	23.	0.	10.	5.69	43.78	33.28	0.09	9.52	8.20	4.0	8.98	24.0	4.4
7	29	76	1	1300000.	790000.	830000.	230000.	20.57	47.70	17.46	1.17	16.48	14.16	10.0	8.12	17.0	4.7
7	29	76	2	790.	330.	1000.	120.					23.36	19.52	11.0	8.88	24.5	15.6
7	29	76	3	140.	20.	100.	8.					25.32	25.68	2.7	8.43	24.5	7.6

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP *C*	DO MG/L
7	29	76	4	140.	130.	67.	49.					20.08	15.20	10.0	8.75	25.0	13.5
7	29	76	5	1700.	13.	67.	7.					8.64	6.64	5.5	9.12	24.5	4.0
7	29	76	6	940.	70.	0.	13.					6.80	4.44	5.7	9.30	25.0	13.9
7	29	76	7	130.	14.	100.	7.					5.64	4.12	3.8	9.29	24.5	10.0
7	29	76	8	460.	5.	250.	4.					6.60	5.28	3.2	7.23	24.5	9.1
7	29	76	9	460.	13.	110.	6.	3.12	39.43	20.29	0.50	5.32	4.28	3.3	9.24	25.0	9.8
8	3	76	1	790000.	790000.	0.	0.	8.87	53.49	28.01	3.31	25.24	20.08	12.0	7.76	15.8	4.5
8	3	76	2	1400.	110.	730.	26.					18.36	14.80	14.0	8.50	23.0	4.5
8	3	76	3	1100.	33.	600.	34.					4.76	4.76	3.0	7.98	23.2	1.1
8	3	76	4	330.	33.	100.	14.					23.68	18.60	12.0	9.02	23.8	10.6
8	3	76	5	220.	49.	1.	12.					4.04	3.60	3.8	8.52	24.1	1.8
8	3	76	6	3500.	33.	200.	21.					31.60	27.20	12.0	9.12	24.0	6.5
8	3	76	7	170.	33.	1.	15.					22.12	14.92	14.0	9.15	24.2	7.2
8	3	76	8	130.	8.	1.	2.					7.16	6.00	4.8	9.13	26.0	5.5
8	3	76	9	220.	11.	33.	6.	2.71	45.02	41.33	1.05	5.96	5.48	3.8	9.10	24.5	3.9
8	5	76	1	1700000.	260000.	720000.	80000.	13.80	23.34	8.53	1.15	39.20	22.28	15.0	7.31	16.5	3.8
8	5	76	2	4900.	110.	400.	20.					15.32	12.24	14.0	8.12	21.5	4.3
8	5	76	3	16000.	170.	470.	79.					4.76	4.76	3.1	8.04	21.0	2.2
8	5	76	4	280.	110.	170.	34.					20.68	14.84	16.0	8.12	22.0	5.0
8	5	76	5	110.	31.	100.	11.					8.28	6.92	4.6	8.53	22.5	4.4
8	5	76	6	3500.	70.	67.	26.					11.64	9.32	6.4	9.00	23.0	7.1
8	5	76	7	33.	5.	1.	1.					8.64	7.12	5.6	9.07	23.0	5.4
8	5	76	8	460.	0.	1.	2.					14.44	10.60	8.3	9.02	23.0	4.7
8	5	76	9	5400.	13.	100.	10.	3.75	46.39	36.07	1.31	5.40	8.12	4.8	9.00	23.0	3.9
8	10	76	1	1300000.	330000.	740000.	150000.	23.75	65.74	9.53	1.98	35.52	26.28	12.0	7.68	16.8	3.9
8	10	76	2	1300.	80.	240.	31.					20.20	16.72	15.0	7.93	21.8	0.8
8	10	76	3	3500.	700.	1300.	130.					17.84	15.48	6.4	7.97	21.4	10.2
8	10	76	4	130.	79.	100.	29.					31.00	25.48	22.0	9.13	22.0	11.1
8	10	76	5	280.	4.	50.	3.					11.40	10.40	5.4	9.09	22.9	14.0
8	10	76	6	3500.	22.	200.	33.					24.28	19.04	12.0	9.08	22.5	7.9
8	10	76	7	31.	13.	50.	2.					25.88	21.84	12.0	9.05	22.5	3.7
8	10	76	8	280.	2.	50.	1.					38.08	29.20	22.0	8.99	22.5	2.7
8	10	76	9	27.	5.	50.	1.	4.99	54.88	43.33	4.18	12.20	11.00	8.5	8.95	22.8	2.5
8	12	76	1	940000.	230000.	910000.	160000.	13.88	54.91	14.07	1.57	60.24	54.88	8.0	7.82	15.5	3.3
8	12	76	2	3300.	130.	1100.	208.					53.40	44.44	7.5	7.90	21.0	0.7
8	12	76	3	13000.	50.	470.	69.					15.80	13.48	7.7	8.54	21.0	7.5
8	12	76	4	130.	23.	100.	19.					32.60	25.16	19.0	9.18	21.0	7.6
8	12	76	5	1800.	13.	50.	8.					10.76	9.08	4.9	9.18	22.0	9.3
8	12	76	6	1700.	33.	50.	26.					19.40	15.08	17.0	9.00	21.0	3.0
8	12	76	7	140.	5.	50.	5.					16.24	11.16	14.0	8.97	22.0	2.7
8	12	76	8	630.	0.	50.	2.					13.96	9.92	9.5	8.93	22.0	2.0
8	12	76	9	790.	0.	50.	3.	4.17	51.97	45.96	1.73	8.60	7.04	7.6	8.91	22.0	2.0
8	17	76	1	330000.	230000.	2000000.	3300.	14.75	68.69	6.78	2.48	22.52	17.64	13.0	7.75	16.0	5.5
8	17	76	2	230.	50.	286.	23.					14.76	11.56	10.0	8.23	20.0	1.3
8	17	76	3	170.	20.	20.	32.					11.68	10.20	7.1	8.60	20.0	4.3
8	17	76	4	130.	27.	20.	18.					36.96	29.72	22.0	9.21	20.0	10.4
8	17	76	5	170.	49.	27.	43.					12.80	9.52	8.4	9.00	20.0	5.9
8	17	76	6	1700.	79.	20.	25.					25.92	23.84	21.0	9.20	20.0	6.3

TABLE E-1. CONTINUED

MONTH	DAY	YEAR	SAMPLE NUMBER	MPN TC /100ML	MPN FC /100ML	MF TC /100ML	MF FC /100ML	BOD5 MG/L	UNFILT COD MG/L	FILT COD MG/L	AMMONIA MG/L	SS MG/L	VSS MG/L	TURB JTU	PH	TEMP "C"	DO MG/L
8	17	76	7	140.	46.	20.	21.					34.72	17.80	24.0	9.11	20.0	5.5
8	17	76	8	94.	5.	4.	1.					46.52	40.12	26.0	9.00	20.0	6.0
8	17	76	9	94.	5.	300.	7.	6.36	89.33	44.41	1.19	24.72	19.28	18.0	9.06	20.0	5.0
8	19	76	1	490000.	80000.	500000.	33000.	28.77	102.66	16.19	1.96	48.28	31.80	10.0	7.92	16.5	4.6
8	19	76	2	24000.	16000.	6700.	230.					9.24	8.12	9.0	8.10	20.0	3.3
8	19	76	3	1700.	80.	0.	26.					13.24	10.84	7.7	8.50	20.0	3.5
8	19	76	4	490.	79.	0.	15.					34.24	25.00	23.0	9.32	20.0	11.0
8	19	76	5	330.	13.	0.	1.					29.60	22.68	12.0	8.98	20.5	3.6
8	19	76	6	2800.	110.	0.	42.					39.00	29.60	26.0	9.40	20.0	8.4
8	19	76	7	2800.	49.	0.	12.					45.84	34.72	31.0	9.39	20.5	10.2
8	19	76	8	1800.	0.	0.	9.					39.20	36.04	29.0	9.31	21.0	10.4
8	19	76	9	2800.	22.	0.	3.	7.40	83.37	46.93	0.77	32.20	25.72	21.0	9.30	21.0	10.4
8	24	76	1	790000.	110000.	790000.	86000.	14.07	63.92	14.67	1.73	23.48	18.48	12.0	7.57	16.0	5.0
8	24	76	2	7900.	2200.	4600.	530.					22.08	19.08	12.0	8.75	20.0	16.3
8	24	76	3	17000.	1300.	76.	160.					25.55	22.60	10.0	8.73	20.0	5.7
8	24	76	4	2800.	49.	64.	13.					67.33	56.80	43.0	9.31	21.0	15.2
8	24	76	5	1800.	22.	70.	12.					20.00	17.90	11.0	9.03	21.0	5.5
8	24	76	6	7900.	11.	10.	7.					2.10	18.96	20.0	9.52	21.0	15.7
8	24	76	7	1700.	33.	10.	35.					21.44	28.12	30.0	9.48	21.0	6.2
8	24	76	8	940.	33.	12.	9.					35.24	29.85	28.0	9.60	21.0	9.2
8	24	76	9	9200.	17.	40.	7.	8.17	77.74	38.45	*****	34.70	30.04	28.0	9.59	21.0	9.9

A ZERO FOR MPN TC AND MPN FC INDICATES A COUNT OF LESS THAN TWO PER 100 ML. DATA NOT TAKEN IS REPRESENTED BY *****.

APPENDIX F

CHLOR-I

```
      DIMENSION R(4,4),S(4,4),SUM(4),SSUM(4),ASUM(4),SE(4),RSQ(4),CV(4),
     *GET(4)
      DATA GET/17.5,35.0,49.5,999./
C     COEFFICIENTS ARE READ IN.
      READ(5,54)SRATIO,TADJ,CORNH3,TADJ2

   54 FORMAT(4F10.5)
      WRITE(6,55)SRATIO,TADJ,CORNH3

   55 FORMAT(14X,'SRATIO = ',F5.2,14X,'TEMP ADJUSTMENT = ',F6.2,14X,'ORG
     *ANIC NITROGEN CORRECTION = ',F5.2/)
      READ(5,100)F,NN
  100 FORMAT(F5.2,I5)
      READ(5,200)CHOCLT,CTCOD,CNH2CL,CTOTAL,CFECAL,BNH2CL,BHOCLT
  200 FORMAT(8F10.5)
      WRITE(6,300)F,CHOCLT,CTCOD,CNH2CL,CTOTAL,CFECAL,BNH2CL,BHOCLT
  300 FORMAT(53X,'SETTLING FRACTION = ',F5.2//54X,'STOICIOMETRIC CONSTAN
     *TS'/15X,'CHOCLT = ',F5.2,15X,'CTCOD = ',F5.2,15X,'CNH2CL = ',F5.2,
     *15X,'CTOTAL = ',F5.2/15X,'CFECAL = ',F5.2,15X,'BNH2CL = ',F5.2,15X
     *,'BHOCLT = ',F5.2,15X,'ALPHA = ',F5.2/)
      READ(5,500)CC1,CC2,CC3,CC4,CC5,CC6,CC7,CC8,CC9
  500 FORMAT(3F20.5)
      WRITE(6,600)CC1,CC2,CC3,CC4,CC5,CC6,CC7,CC8,CC9
  600 FORMAT(57X,'RATE COEFFICIENTS'/19X,'CC1 = ',E12.5,19X,'CC2 = ',E12
     *.5,19X,'CC3 = ',E12.5/19X,'CC4 = ',E12.5,19X,'CC5 = ',E12.5,19X,'C
     *C6 = ',E12.5/19X,'CC7 = ',E12.5,19X,'CC8 = ',E12.5,19X,'CC9 = ',E1
     *2.5/)
      READ(5,4000)DT,TFIN,PRI
 4000 FORMAT(3F5.2)
      DO 160 JJJ=1,NN
      ANH2CL=0.
      ATPRNT=0.
C     THE INITIAL CONDITIONS OF FIELD DATA ARE READ IN.
      READ(5,1000)IM,IDAY,IYR,TOTALC,FECALC,TCOD,SCOD,ANH3T,SULF,SS,PH,T
     *EMP
 1000 FORMAT(4X,I2,I2,I1,2X,2F8.0,2F5.2,F4.2,F3.2,F5.2,8X,F4.2,F3.1)
      READ(5,1100)CL2
 1100 FORMAT(F5.2)
C     CHLORINE AND COLIFORM DATA ARE STORED FOR FUTURE USE IN MAKING A
C     COMPARISON BETWEEN ACTUAL AND PREDICTED VALUES.
      R(1,1)=CL2
      R(2,1)=CL2
      R(3,1)=FECALC
      R(4,1)=TOTALC
      S(1,1)=CL2
      S(2,1)=CL2
      S(3,1)=FECALC
      S(4,1)=TOTALC
      WRITE(6,3000)
 3000 FORMAT('0',1X,'TIME',4X,'FREE CHLOR',5X,'COMB CHLOR',3X,'SULFIDE',
     *6X,'NH3T',5X,'FECAL COLI',2X,'TOTAL COLI',6X,'SS',9X,'SCOD'/1X,'(M
     *IN)',6X,'(MG/L)',9X,'(MG/L)'6X,'(MG/L)',5X,'(MG/L)',5X,'(/100ML)',
     *4X,'(/100ML)',5X,'(MG/L)',6X,'(MG/L)')
      T=0.
C     INITIAL CONDITIONS ARE WRITTEN.
      WRITE(6,3500)T,CL2,ANH2CL,SULF,ANH3T,FECALC,TOTALC,SS,SCOD
 3500 FORMAT(1X,F6.3,3X,8E12.5)
      RHOCL=0.
      TPRNT=0.
      SLIMIT=0.1
C     COEFFICIENTS ARE ADJUSTED FOR TEMPERATURE.
      FACT1=TADJ**(TEMP-20.)
      FACT2=TADJ2**(TEMP-20.)
      BC4=CC4*FACT2
      BC5=CC5*FACT2
      BC6=CC6*FACT1
      BC7=CC7*FACT1
      BC8=CC8*FACT1
      BC9=CC9*FACT1
C     THE UPTAKE OF CHLORINE BY SULFICE IS CALCULATED.
      IF(SULF.LE.SLIMIT)GO TO 5
      SULFR=SLIMIT+(SULF-SLIMIT)*EXP(-.14094*CL2)
      SULFU=(SULF-SULFR)/32000.
      SULF=SULFR
      RHOCL=SRATIO*SULFU
C     FOR CONDITIONS WHERE BREAKPCINT CHLORINATION IS A POSSIEILITY, THE
C     FREE AND COMBINED CHLORINE AFTER BREAKPOINT REACTIONS HAVE OCCURRED
C     IS ESTIMATED.
    5 HOCLT=CL2/71000.
      HOCLT=HOCLT-RHOCL
      IF(HOCLT.LE.0.)HOCLT=0.
      ANH3T=ANH3T/17000.
      IF(ANH3T.LE.0.00)GO TO 6
      ARATIO=HOCLT/ANH3T
      GO TO 7
    6 ARATIO=1.0
    7 BP=1.65
      IF(ARATIO.GT.1.0)GO TO 10
      ANH2CL=HOCLT
      HOCLT=0.
      GO TO 40
   10 PEAK=1.0+CORNH3
      IF(ARATIO.GT.PEAK)GO TO 20
      ANH2CL=HOCLT
      HOCLT=0.
      GO TO 40
   20 BBP=BP+CORNH3
      SLOPE=(-1.0/(BBP-PEAK))
      IF(ARATIO.GT.BBP)GO TO 30
      ANH2CL=(((ARATIO-PEAK)*SLOPE)+PEAK)*ANH3T
      ANH3T=ANH3T-((ARATIO-PFAK)*ANH3T)
      HOCLT=0.
      GO TO 40
   30 ANH2CL=(((BBP-PEAK)*SLOPE)+PEAK)*ANH3T
      HOCLT=(ARATIO-BBP)*ANH3T
      ANH3T=0.
   40 CONTINUE
      ANH3T=ANH3T*17000.
      HOCLT=HOCLT*71000.
      ANH2CL=ANH2CL*71000.
      IF(HOCLT.LE.0.)CLX=.01
      IF(HOCLT.GT.0.)CLX=HOCLT
      IF(ANH2CL.LE.0.)CLY=.01
      IF(ANH2CL.GT.0.)CLY=ANH2CL
      SS=SS-F*SS
      ITIC=1
      JP=0
   50 IF(FECALC.LE.0.01)FECALC=0.
      IF(TOTALC.LE.0.01)TOTALC=0.
      IF(HOCLT.LE.0.0.AND.ANH2CL.LE.0.0)GO TO 80
      IF(HOCLT.LT.0.01)HOCLT=0.
      IF(ANH2CL.LT.0.01)ANH2CL=0.
C   THE DIFFERENTIAL RATE EXPRESSIONS ARE DEFINED.
      DSCOD=CC1*HOCLT*(TCOD-SCOD)
      DSS=(CC2*HOCLT*SS)+(CC3*ANH2CL*SS)
      DHOCLT=BC4*((HOCLT/CLX)**CHOCLT)*(TCOD**CTCOD)
      DNH2CL=BC5*((ANH2CL/CLY)**CNH2CL)*(TCOD**CTCOD)
      DTOTAL=BC6*(TOTALC**CTOTAL)*(ANH2CL**BNH2CL)+BC7*(TOTALC**CTOTAL)*
     *(HOCLT**BHOCLT)
      DFECAL=BC8*(FECALC**CFECAL)*(ANH2CL**BNH2CL)+BC9*(FECALC**CFECAL)*
     *(HOCLT**BHOCLT)
      IF(T.LE.GET(ITIC))GO TO 101
      K=ITIC+1
C   CALCULATED VALUES OF CHLORINE AND COLIFORM ARE STORED FOR FUTURE USE .
      R(1,K)=HOCLT
      R(2,K)=ANH2CL
      R(3,K)=FECALC
      R(4,K)=TOTALC
      ITIC=ITIC+1
  101 CONTINUE
      IF(TPRNT.EQ.0.)GO TO 70
      ATPRNT=TPRNT-0.0001
      IF(T.GE.ATPRNT)GO TO 60
      GO TO 70
C   PREDICTED VALUES ARE WRITTEN AT TIME INTERVALS SPECIFIED BY PRINT
C   COMMANDS.
   60 WRITE(6,5000)T,HOCLT,ANH2CL,SLLF,ANH3T,FECALC,TOTALC,SS,SCOD
 5000 FORMAT(1X,F6.3,3X,8E12.5)
   70 IF(T.GE.ATPRNT)TPRNT=TPRNT+PRI
      IF(T.GE.TFIN)GO TO 80
C   INITIALIZATION SUBROUTINE IS CALLED.
      CALL INTI(T,DT,2,JP)
C   A SUBROUTINE FOR SOLVING FIRST, SECOND, OR FOURTH ORDER ORDINARY
C   DIFFERENTIAL EQUATIONS BY A GENERAL RUNGE KUTTA SOLUTION TECHNIQUE
C   IS CALLED.
      CALL INT(SCOD,DSCOD)
      CALL INT(SS,DSS)
      CALL INT(HOCLT,DHOCLT)
      CALL INT(ANH2CL,DNH2CL)
      CALL INT(TOTALC,DTOTAL)
      CALL INT(FECALC,DFECAL)
      GO TO 50
   80 WRITE(6,5500)
 5500 FORMAT('0',58X,'OBSERVED VALUES'/)
C   OBSERVED DATA AT THREE TIME INTERVALS ARE PRINTED AND STORED FOR
C   COMPARISON WITH PREDICTED VALUES AT THOSE SAME TIME INTERVALS.
      DO 90 J=1,3
      READ(5,6000)IS,TOTALC,FECALC,SCOD,ANH3T,SULF,SS,ANH2CL,HOCLT
 6000 FORMAT(9X,I2,2F8.0,5X,F5.2,F4.2,F3.2,F5.2,22X,2F4.2)
      IF((IS.EQ.12).OR.(IS.EQ.15).OR.(IS.EQ.18).OR.(IS.EQ.21))TT=17.5
      IF((IS.EQ.13).OR.(IS.EQ.16).OR.(IS.EQ.19).OR.(IS.EQ.22))TT=35.0
      IF((IS.EQ.14).OR.(IS.EQ.17).OR.(IS.EQ.20).OR.(IS.EQ.23))TT=49.6
      L=J+1
      S(1,L)=HOCLT
      S(2,L)=ANH2CL
      S(3,L)=FECALC
      S(4,L)=TOTALC
      WRITE(6,7000)TT,HOCLT,ANH2CL,SULF,ANH3T,FECALC,TOTALC,SS,SCOD
 7000 FORMAT(1X,F6.3,3X,8E12.5)
   90 CONTINUE
C     VALUES OF R SQUARED, STANDARD ERROR, AND COEFFICIENT OF VARIATION
C     ARE CALCULATED FOR FREE AND COMBINED AND TOTAL AND FECAL COLIFORM.
      DO 103 I=1,4
      DO 102 L=1,4
      SUM(I)=SUM(I)+((R(I,L)-S(I,L))**2.)
  102 CONTINUE
  103 CONTINUE
      DO 131 I=1,2
      DO 130 L=1,4
      K=I+2
      ASUM(I)=ASUM(I)+S(I,L)
      IF(S(K,L).EQ.0.)S(K,L)=1.
      ASUM(K)=ASUM(K)+ALOG(S(K,L))
  130 CONTINUE
  131 CONTINUE
      AN=4.
      DO 140 I=1,2
      K=I+2
      ASUM(I)=ASUM(I)/AN
  140 ASUM(K)=EXP(ASUM(K)/AN)
      DO 121 I=1,4
      DO 120 L=1,4
      SSUM(I)=SSUM(I)+((S(I,L)-ASUM(I))**2.)
  120 CONTINUE
  121 CONTINUE
      DO 104 I=1,4
      SE(I)=SQRT(SUM(I)/AN)
      IF(SSUM(I).EQ.0.)GO TO 110
      RSQ(I)=1.-(SUM(I)/SSUM(I))
  110 IF(ASUM(I).EQ.0.)GO TO 104
      CV(I)=SE(I)/ASUM(I)
  104 CONTINUE
      DO 108 I=1,4
      IF(RSQ(I).EQ.0.)GO TO 105
      GO TO 106
  105 RSQ(I)=10.0E10
      GO TO 107
  106 RRSQ=RRSQ+RSQ(I)
      N1=N1+1
  107 STDE=STDE+SE(I)
      M=M+1
      IF(CV(I).EQ.0.)CV(I)=10.0E10
      IF(CV(I).GT.10.0E09)GO TO 108
      COV=COV+CV(I)
      N2=N2+1
  108 CONTINUE
      IF(N1.EQ.0.)N1=1
      IF(M.EQ.0)M=1
      IF(N2.EQ.0)N2=1
      RRSQ=RRSQ/N1
      STDE=STDE/M
      COV=COV/N2
      WRITE(6,8000)
 8000 FORMAT('0',14X,'FREE CHLOR',14X,'COMB CHLOR',14X,'FECAL COLI',14X,
     *' TOTAL COLI',14X,'AVERAGE'//)
      WRITE(6,9000)(RSQ(I),I=1,4),RRSQ
 9000 FORMAT(1X,'R SQUARED',5X,F9.4,15X,F9.4,15X,F9.4,15X,F9.4,13X,F9.4)
      WRITE(6,9100)(SE(I),I=1,4),STDE
```

```
9100 FORMAT(1X,'STD ERROR',3X,E12.4,12X,E12.4,12X,E12.4,12X,E12.4,10X,E
    *12.4)
     WRITE(6,9200)(CV(I),I=1,4),COV
9200 FORMAT(1X,'COEF OF VAR',3X,F9.4,15X,F9.4,15X,F9.4,15X,F9.4,13X,F9.
    *4)
     DO 150 I=1,4
     SUM(I)=0.
     SSUM(I)=0.
     ASUM(I)=0.
     SE(I)=0.
     RSQ(I)=0.
 150 CV(I)=0.
     N1=0
     N2=0
     M=0
     RRSQ=0.
     STDE=0.
     COV=0.
 160 CONTINUE
     STOP
     END
```

```
      SUBROUTINE INTI(TD,DTD,IOD,JP)
C   THIS IS AN INITIALIZATION SUBROUTINE WHICH IS USED IN CONJUNCTION
C   WITH THE SUBROUTINE INT.  IT KEEPS TRACK OF THE TOTAL TIME.
      COMMON/CINT/T,DT,JS,JN,DXA(500),XA(500),IO,JS4
      IF(JP.EQ.1) GO TO 10
      JS=0
      JS4=0
      JP=1
   10 CONTINUE
      IO=IOD
      JN=0
      GO TO (6,5,1,1),IO
    6 JS=2
      GO TO 7
    5 JS=JS+1
      IF(JS.EQ.3)JS=1
      IF(JS.EQ.2)RETURN
    7 DT=DTD
    3 TD=TD+DT
      T=TD
      RETURN
    1 JS4=JS4+1
      IF(JS4.EQ.5)JS4=1
      IF(JS4.EQ.1) GO TO 2
      IF(JS4.EQ.3) GO TO 4
      RETURN
    2 DT=DTD/2.
      GO TO 3
    4 TD=TD+DT
      DT=2.*DT
      T=TD
      RETURN
      END
      SUBROUTINE INT(X,DX)
C     THIS SUBROUTINE SOLVES AN ORDINARY DIFFERENTIAL EQUATION FOR THE
C     DEPENDENT VARIABLE USING EITHER A FIRST, SECOND, OR FOURTH ORDER
C     RUNGE KUTTA SOLUTION TECHNIQUE.
      COMMON/CINT/T,DT,JS,JN,DXA(500),XA(500),IO,JS4
      JN=JN+1
      GO TO (9,8,3,3),IO
    9 X=X+DX*DT
      RETURN
    8 GO TO (1,2),JS
    1 DXA(JN)=DX
      X=X+DX*DT
      RETURN
    2 X=X+(DX-DXA(JN))*DT/2.
      RETURN
    3 GO TO (4,5,6,7),JS4
    4 XA(JN)=X
      DXA(JN)=DX
      X=X+DX*DT
      RETURN
    5 DXA(JN)=DXA(JN)+2.*DX
      X=XA(JN)+DX*DT
      RETURN
    6 DXA(JN)=DXA(JN)+2.*DX
      X=XA(JN)+DX*DT
      RETURN
    7 DXA(JN)=(DXA(JN)+DX)/6.
      X=XA(JN)+DXA(JN)*DT
      RETURN
      END
```

LIST OF VARIABLES USED IN CHLOR-I

ANH2CL = Combined chlorine, mg/l

ARATIO = Ratio of chlorine to NH_3 at T = 0

BHOCLT = Empirical constant--define effect of free chlorine on bacti destruction

BNH2CL = Empirical constant--defines effect of combined chlorine on bacti destruction

CC1-CC9 = Empirical rate constants

CFECAL = Empirical constant used to describe rate of fecal coliform destruction

CHOCLT = Empirical constant used in defining rate of exertion of chlorine demand

CLX = The initial amount of free chlorine

CLY = The initial amount of combined chlorine

CNH2CL = Empirical constant used in defining rate of exertion of combined chlorine demand

CORNH3 = An empirical correction factor to change the shape of the breakpoint curve to compensate for the reaction of chlorine with organic nitrogen

CTCOD = Empirical constant used in defining rate of exertion of chlorine demand

CTOTAL = Empirical constant used to describe rate of total coliform destruction

CV = Coefficient of variation

DT = The time step used in calculating the dependent variable (min.)

F = An empirical constant which specifies the settling fraction of SS which will settle out in a plug flow reactor

HOCLT = Free chlorine, mg/l

NH3T = Total ammonia, mg/l

NN = The number of times the program is to be run

PRI = A print command which specifies at what time interval an answer is to be printed out

RSQ = R squared

SRATIO = The ratio of moles chlorine consumed per mole of sulfide consumed

STDE = Standard error

T = Time, the independent variable, minutes

TADJ = The temperature adjustment factor to account for the changes in bacterial kill with changing temperature

TADJ2 = The temperature adjustment factor to compensate for changes in the rate at which chlorine demand is exerted with changing temperature

TFIN = A control command specifying the length of time for which the simulation is to be made

APPENDIX G

CHLOR-II

```
C     THIS PROGRAM SOLVES A SYSTEM OF N FIRST ORDER ORDINARY DIFFERENTIAL
C     EQUATIONS.  USE IS MADE OF A GENERAL RUNGE KUTTA METHOD OF ORDER TWO
C     WITH A SUBROUTINE IMPLEMENTING A VARIABLE STEP SIZE PROCEDURE.
      DIMENSION Y(10),DY(10),YMAX(10),ERROR(10)
      READ(5,100)PH,TEMPC
  100 FORMAT(2F5.2)
      READ(5,200)DT,DTMIN,DTOUT,TMAX,EPS,N
  200 FORMAT(5F5.2,I5)
      READ(5,300)(Y(I),I=1,N)
  300 FORMAT(8F10.0)
C    Y(1)=HOCLT, Y(2)=NH3T, Y(3)=NH2CL, Y(4)=NHCL2, Y(5)=NOH, Y(6)=TOTAL
C    COLIFORM, Y(7)=FECAL COLIFORM, Y(8)=NO3
      READ(5,400)(YMAX(I),I=1,N)
  400 FORMAT(8F5.0)
      Y(1)=(Y(1)/1000.)/71.
      Y(2)=(Y(2)/1000.)/17.
      TEMPK=TEMPC+273.
      HPLUS=10.**(-PH)
      T=0.
      CKW=10.E-14
      CKNH3=1.71E-05+((TEMPC-20.)*(.016E-05))
      CKHOCL=2.5E-08+((TEMPC-20.)*(.05E-08))
      C0=(C1*CKW)/(CKNH3*CKHOCL)
      C1=(9.7E08)*EXP(-3000./(1.9872*TEMPK))
      C2=((7.6E07)*EXP(-7300./(1.9872*TEMPK)))*(1.+HPLUS)
      FACT1=1.072**(TEMPC-20.)
      C3=.05*FACT1
      C4=1.0E05*FACT1
      C5=2.0E07*FACT1
      C6=4.2E05*FACT1
      C7=2.1E04
      C8=6.2E02
      C9=25.
      OHMIN=CKW/HPLUS
      WRITE(6,500)DT,DTMIN,DTOUT,TMAX
  500 FORMAT(1X,'DT = ',F6.3/1X,'DTMIN = ',F6.3/1X,'DTOUT = ',F6.3/1X,'T
     *MAX = ',F10.3)
      WRITE(6,600)(Y(I),I=1,N),PH,TEMPC
  600 FORMAT(1X,'INITIAL CONDITIONS = ',5X,8E12.5/1X,'PH = ',F5.2,5X,'TE
     *MPC = ',F5.2)
      WRITE(6,700)
  700 FORMAT('0','TIME',5X,'DT',6X,'HOCL',8X,'OCL',8X,'HOCLT',8X,'NH3T',
     *8X,'NH2CL',8X,'NHCL2',8X,'NOH',8X,'TOTC',8X,'FECALC')
      TOUT=0.
      JSTART=1
      K=1
    1 K=K+1
      IF(K.EQ.5)GO TO 5
     THE FUNCTIONS ARE DEFINED.
      CALL DIFFUN(T,Y,DY,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,ANH3,ANH
     *4)
```

```
C    THE RUNGE KUTTA SUBROUTINE IS CALLED WITHOUT USING THE STEP
C    OPTIMIZATION PROCEDURE.
       CALL RK2(N,T,Y,DY,DT,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,ANH3,A
      *NH4)
       T=T+DT
       TOUT=TOUT+DT
       GO TO 6
C    EVERY FIFTH TIME STEP, THE MAIN PROGRAM CALLS THE STEP OPTIMIZATION
C    SUBROUTINE.
     5 CALL DIFSUB(N,T,Y,DY,DT,DTMIN,EPS,YMAX,ERROR,KFLAG,JSTART,C0,C1,C2
      *,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,ANH3,ANH4,TOUT)
     6 HOCL=(HPLUS*Y(1))/(CKHOCL+HPLUS)
       ANH3=(OHMIN*Y(2))/(CKNH3+OHMIN)
       ANH4=Y(2)-ANH3
       OCL=Y(1)-HOCL
       IF(K.EQ.5)K=0
       IF(TOUT.LT.TOUTT)GO TO 3
       TOUT=0.
       NN=N-1
       WRITE(6,800)T,DT,HOCL,OCL,(Y(I),I=1,NN),KFLAG
   800 FORMAT(1X,F8.4,1X,F8.4,1X,9F12.4,1X,I3)
     3 IF(T.GT.TMAX)GO TO 4
       GO TO 1
     4 STOP
       END
      SUBROUTINE DIFSUB (N,T,Y,DY,DT,DTMIN,EPS,YMAX,ERROR,KFLAG,JSTART,C
     *0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,ANH3,ANH4,TOUT)
C     THIS SUBROUTINE SELECTS THE LARGEST STEP SIZE WHICH WILL KEEP THE
C     ERROR BELOW THAT WHICH IS SPECIFIED.
      DIMENSION Y(10),DY(10),YMAX(10),YSAVE(10),Y1(10),Y2(10),Y3(10),ERR
     *OR(10),DYN(10),YMAXSV(10)
      IF(JSTART.LT.0)GO TO 2
C     SAVE THE VALUES OF Y AND YMAX IN CASE A RESTART IS NECESSARY.  YMAX
C     SHOULD BE INITIALIZED TO +1.0 BEFORE THE FIRST ENTRY.
      DO 1 I=1,N
      YSAVE(I)=Y(I)
    1 YMAXSV(I)=YMAX(I)
C     CALCULATE THE INITIAL DERIVATIVES.
      CALL DIFFUN (T,Y,DYN,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,ANH3,A
     *NH4)
      GO TO 4
C     RESTORE THE INITIAL VALUES OF Y AND YMAX FOR A RESTART.
    2 DO 3 I=1,N
      Y(I)=YSAVE(I)
    3 YMAX(I)=YMAXSV(I)
    4 KFLAG=1
C     SAVE THE FINAL VALUE OF T AND CALCULATE THE HALF STEP.
    5 A=DT+T
      AA=DT+TOUT
      HHALF=DT*0.5
C     PERFORM ONE FULL RUNGE KUTTA STEP.
      CALL RK1(N,T,YSAVE,DYN,DT,Y1,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OC
     *L,ANH3,ANH4)
C     PERFORM TWO HALF INTERVAL RUNGE KUTTA STEPS.
      CALL RK1(N,T,YSAVE,DYN,HHALF,Y2,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL
     *,OCL,ANH3,ANH4)
      THALF=T+HHALF
      CALL DIFFUN(THALF,Y2,DY,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,ANH
     *3,ANH4)
      CALL RK1(N,THALF,Y2,DY,HHALF,Y3,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL
     *,OCL,ANH3,ANH4)
      ERRMAX=0.
C     CALCULATE THE NEW MAX Y'S, THE ERRORS, AND THE MAX RELATIVE ERRORS.
      DO 6 I=1,N
      YMAX(I)=AMAX1(ABS(Y1(I)),ABS(Y2(I)),ABS(Y3(I)))
      IF(YMAX(I).LE.0.)GO TO 9
      ERROR(I)=ABS((Y3(I)-Y1(I))/3.0)
      ERRMAX=AMAX1(ERRMAX,ERROR(I)/(EPS*YMAX(I)))
C     CALCULATE THE IMPROVED VALUE OF Y BY ELIMINATING THE ESTIMATED ERROR.
    9 Y(I)=(4.0*Y3(I)-Y1(I))/3.0
    6 CONTINUE
      IF(ERRMAX.LE.0.)DT=DT*2.0
      IF(ERRMAX.GT.0.)DT=DT*ERRMAX**(-0.2)*0.99
      IF(ERRMAX.GT.1.0)GO TO 8
      KFLAG=1
    7 T=A
      TOUT=AA
      RETURN
    8 IF(DT.GT.DTMIN)GO TO 5
      IF(KFLAG.LT.0)GO TO 7
      DT=DTMIN
      KFLAG=-1
      GO TO 5
      END
      SUBROUTINE RK1(N,T,Y,DY,DT,Y1,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,O
     *CL,ANH3,ANH4)
C    THIS SUBROUTINE PERFORMS ONE RUNGE KUTTA STEP OF ORDER TWO.
C    IT IS USED IN CONJUNCTION WITH THE STEP OPIMIZATION SUBROUTINE.
      DIMENSION Y(10),DY(10),Y1(10),Y2(10),DY1(10),DY2(10)
      DO 1 I=1,N
      DY1(I)=DY(I)
    1 Y2(I)=Y(I)+DY(I)*DT
      CALL DIFFUN(T,Y2,DY2,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,ANH3,A
     *NH4)
      DO 2 I=1,N
    2 Y1(I)=Y2(I)+((DY2(I)-DY1(I))*DT/2.)
      RETURN
      END
```

```
      SUBROUTINE RK2(N,T,Y,DY,DT,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,
     *ANH3,ANH4)
C    THIS SUBROUTINE PERFORMS ONE RUNGE KUTTA STEP OF ORDER TWO.
C    IT IS USED WITHOUT THE STEP OPTIMIZATION SUBROUTINE.
      DIMENSION Y(10),DY(10),YY(10),DY1(10)
      DO 1 I=1,N
      DY1(I)=DY(I)
    1 YY(I)=Y(I)+DY(I)*DT
      CALL DIFFUN(T,YY,DY,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,ANH3,AN
     *H4)
      DO 2 I=1,N
    2 Y(I)=YY(I)+((DY(I)-DY1(I))*DT/2.)
      RETURN
      END
      SUBROUTINE DIFFUN(T,Y,DY,C0,C1,C2,C3,C4,C5,C6,C7,C8,C9,HOCL,OCL,AN
     *H3,ANH4)
C    THIS SUBROUTINE EVALUATES THE DERIVATIVES AT THE SPECIFIED POINTS
C    (T,Y(I)).
      DIMENSION Y(10),DY(10)
      TCOD=90.35
      CC4=.003
      CC5=.0016
      CC6=.0009
      CC7=.003
      CC8=.0014
      CC9=.006
      CCL2=30.
      R1=C1*HOCL*ANH3
      R2=C2*HOCL*Y(3)
      R3=C3*Y(4)
      R4=C4*Y(5)*Y(4)
      R5=C5*Y(5)*Y(3)
      R6=C6*Y(5)*(HOCL**2.)
      Y(1)=Y(1)*71000.
      Y(3)=Y(3)*71000.
      Y(4)=Y(4)*71000.
      IF(Y(1).LE.0.0)GO TO 6
      R8=(CC4*(Y(1)/CCL2)**2.5)*TCOD
    6 SUM=Y(3)+Y(4)
      IF(SUM.LE.0.0)GO TO 1
      R9=(CC5*((SUM/CCL2)**7.4)*TCOD)
      R10=CC6*(Y(6)**1.1)*((SUM)**1.35)
      R12=CC8*(Y(7)**1.08)*((SUM)**1.35)
      GO TO 2
    1 R9=0.
      R10=0.
      R12=0.
    2 IF(Y(1).LE.0.0)GO TO 3
      IF(Y(6).LE.0.0)R11=0.0
      IF(R11.LE.0.0)GO TO 4
      R11=CC7*(Y(6)**1.1)*(Y(1)**1.3)
    4 IF(Y(7).LE.0.0)R13=0.0
      IF(R13.LE.0.0)GO TO 5
      R13=CC9*(Y(7)**1.08)*(Y(1)**1.3)
      GO TO 5
    3 R11=0.0
      R13=0.0
    5 R8=R8/71000.
      R9=R9/71000.
      DY(1)=-R1-R2+R4-R6-R8
      DY(2)=-R1
      DY(3)=R1-R2-R5-R9
      DY(4)=R2-R3-R4-R9
      DY(5)=R3-R4-R5-R6
      DY(6)=-R10-R11
      DY(7)=-R12-R13
      DY(8)=R6
      Y(1)=Y(1)/71000.
      Y(3)=Y(3)/71000.
      Y(4)=Y(4)/71000.
      RETURN
      END
```

LIST OF VARIABLES USED IN CHLOR-II

C1-C9 = Rate constants, breakpoint reactions

CC4-CC9 = Rate constants developed in CHLOR-I

DT = The initial step size

DTMIN = The minimum step size that should be allowed

DTOUT = The interval for printing out the values of dependent variables

DY = The values of the derivatives at the start of the interval

EPS = The error test constant

ERROR = The estimated single step error in each component

JSTART = An initialization indicator, JSTART = -1 means to repeat the last step, JSTART = +1 means take a new step

KFLAG = A completion code, KFLAG = +1 means the step was successful, KFLAG = -1 means the requested error was not achieved

N = The number of first order differential equations

T = The independent variable, time (seconds)

TMAX = The end of the interval being considered

Y = The dependent variables

YMAX = The maximum values of the dependent variables

APPENDIX H

COMPARISON OF MOST PROBABLE NUMBER (MPN) AND MEMBRANE FILTER (MF) TECHNIQUE FOR ENUMERATING TOTAL AND FECAL COLIFORM BACTERIA

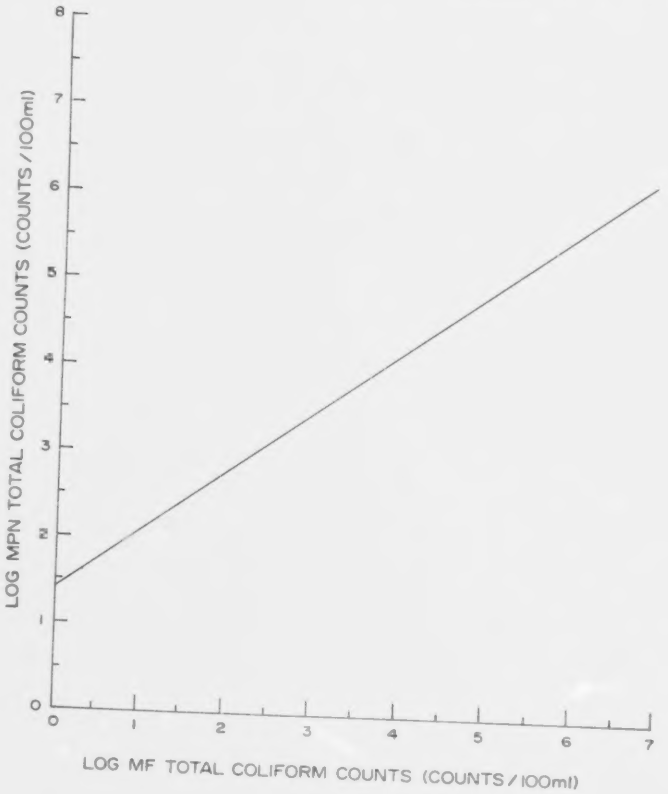

Figure H-1. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for June, 1975.

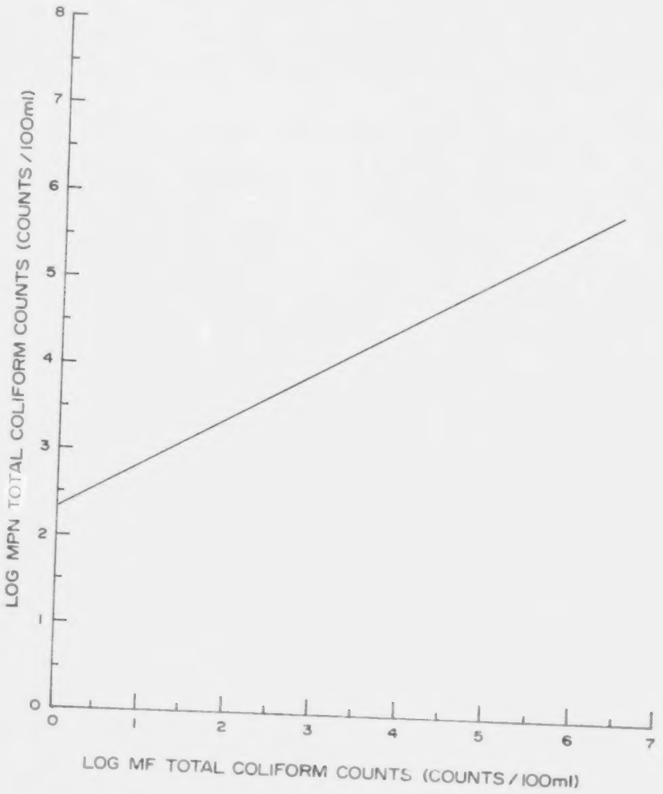

Figure H-2. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for July, 1975.

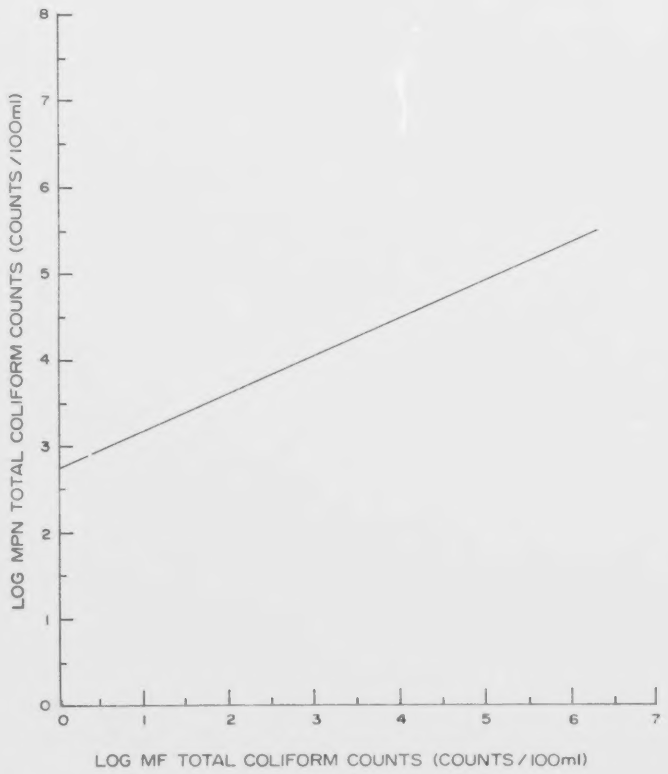

Figure H-3. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for August, 1975.

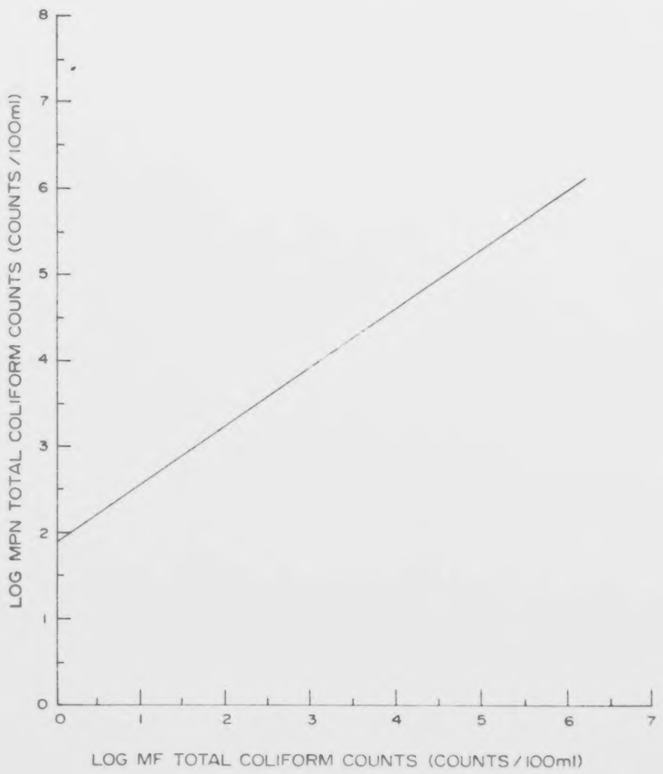

Figure H-4. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for September, 1975.

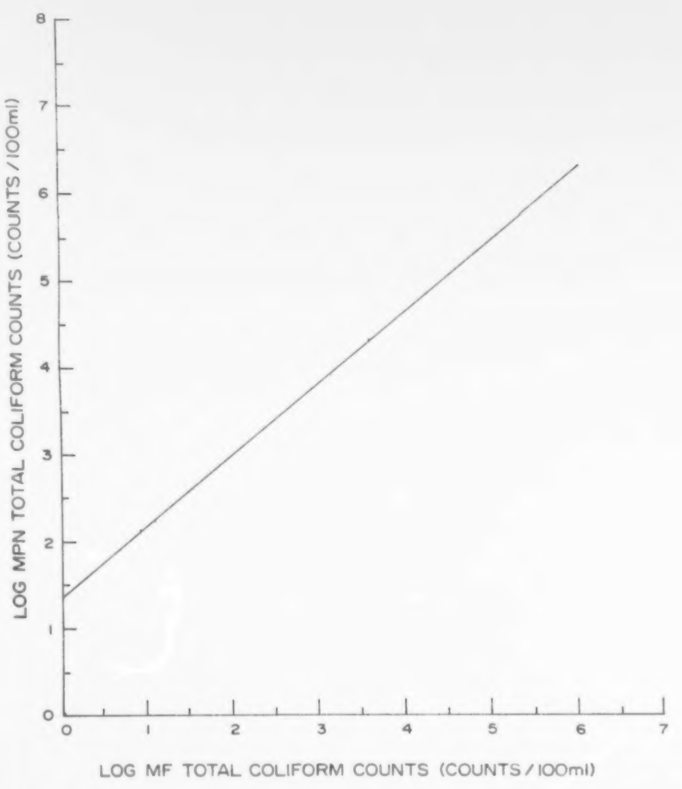

Figure H-5. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for October, 1975.

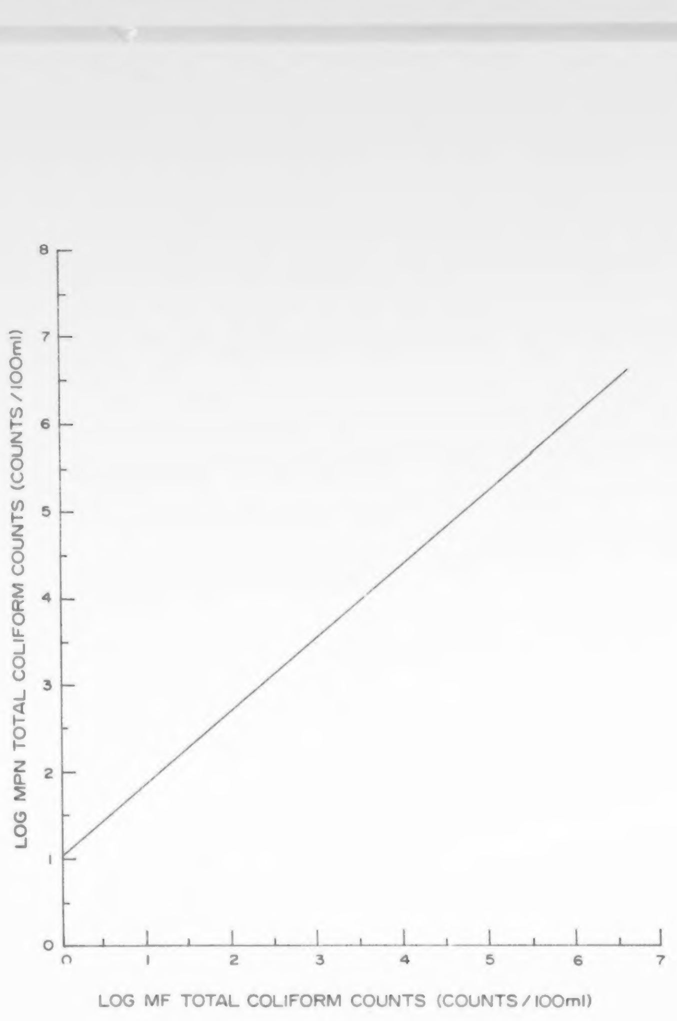

Figure H-6. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for November, 1975.

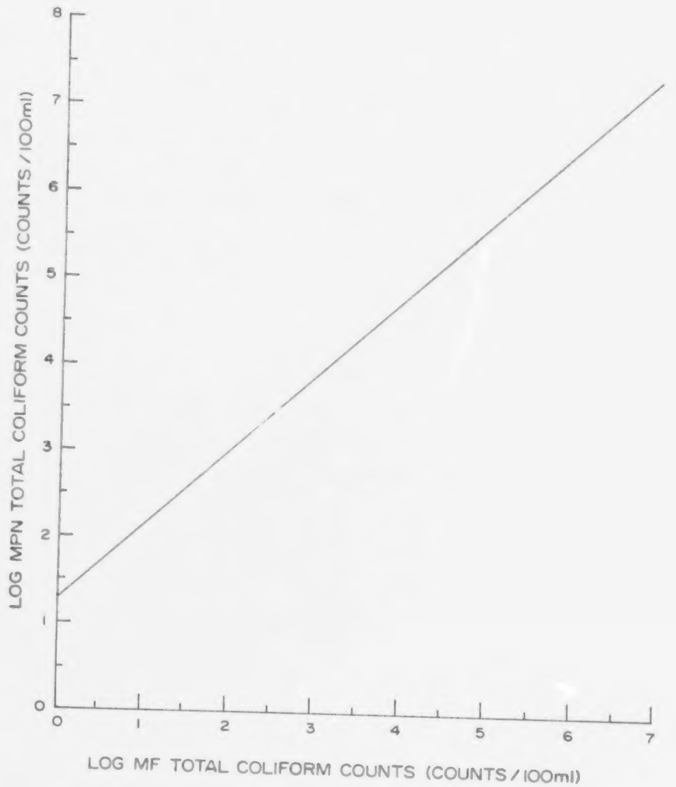

Figure H-7. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for December, 1975.

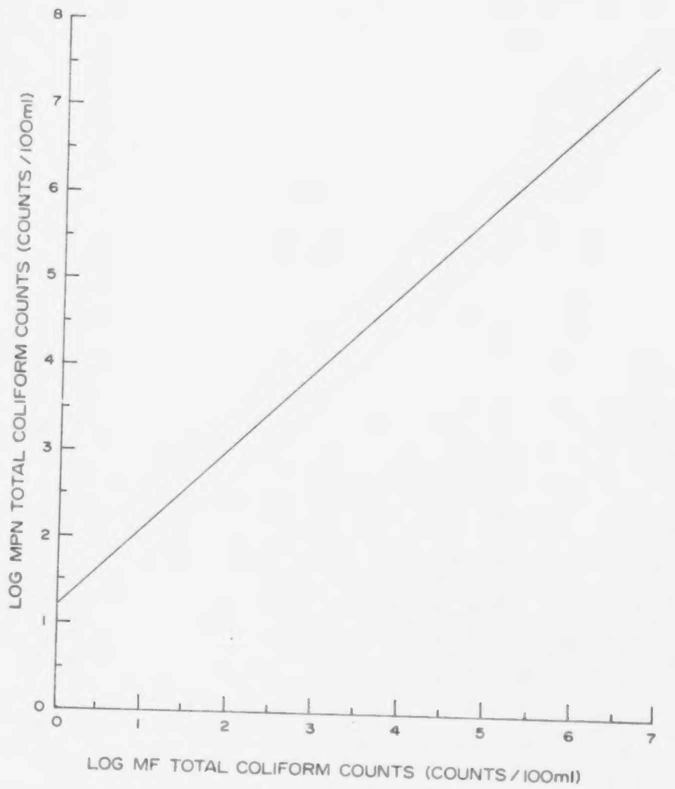

Figure H-8. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for January, 1976.

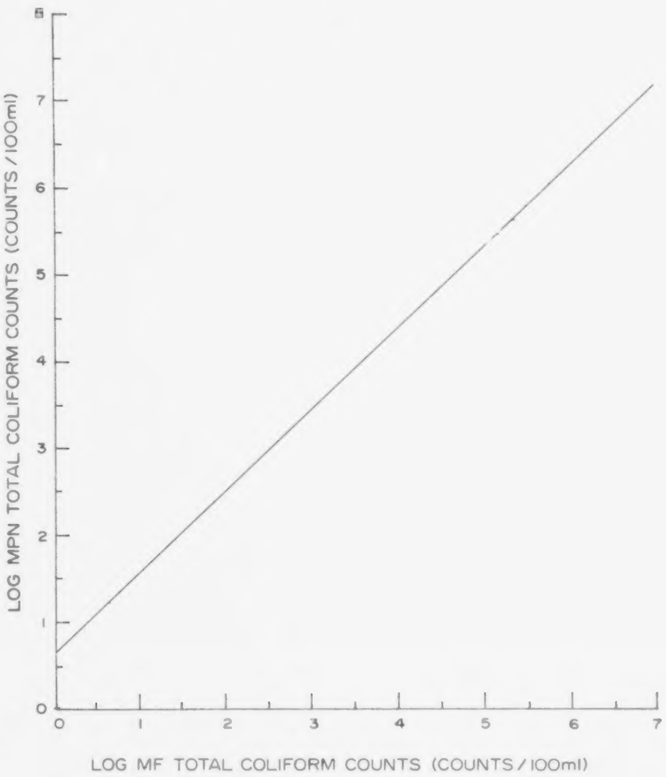

Figure H-9. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for February, 1976.

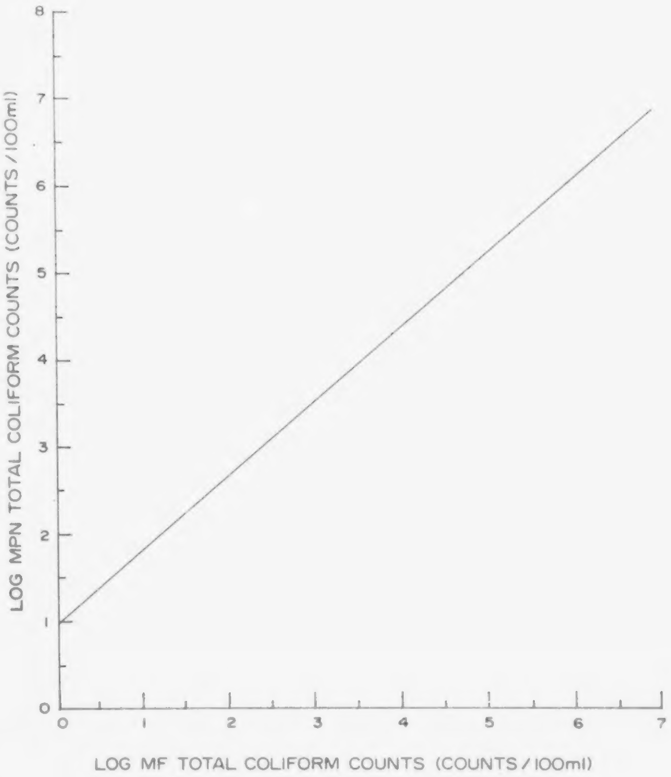

Figure H-10. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for March, 1976.

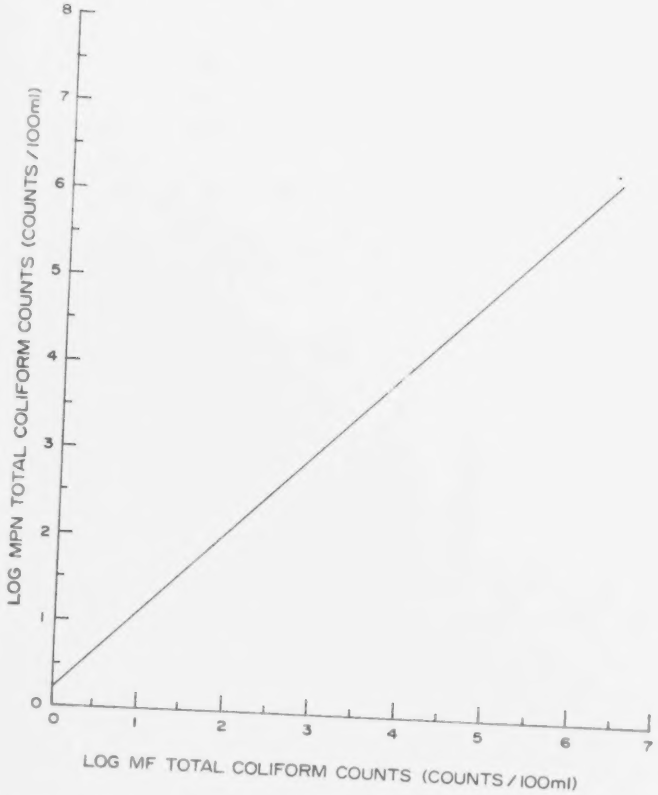

Figure H-11. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for April, 1976.

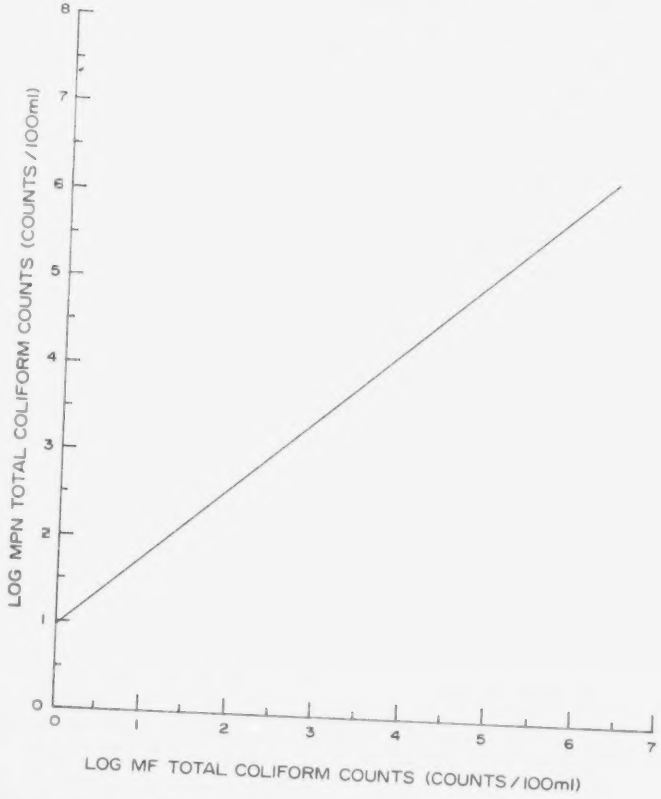

Figure H-12. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for May, 1976.

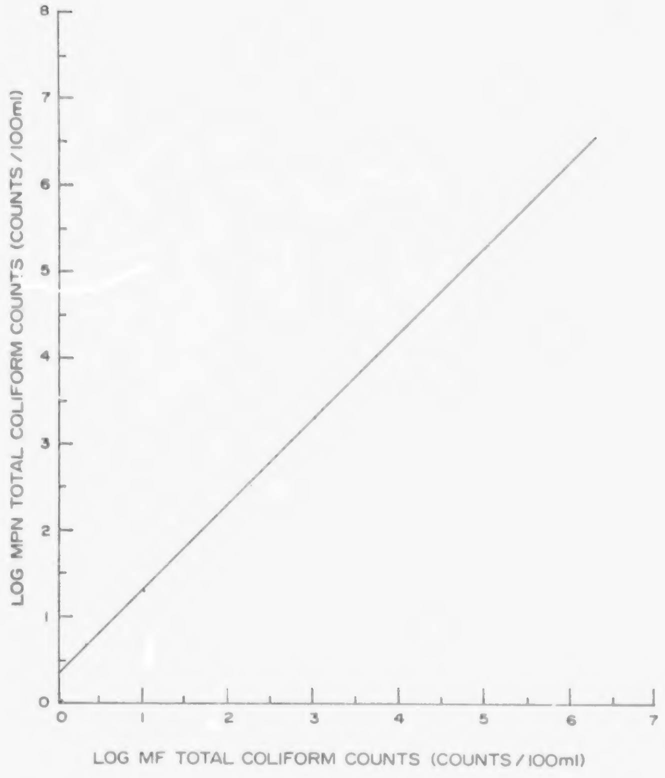

Figure H-13. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for June, 1976.

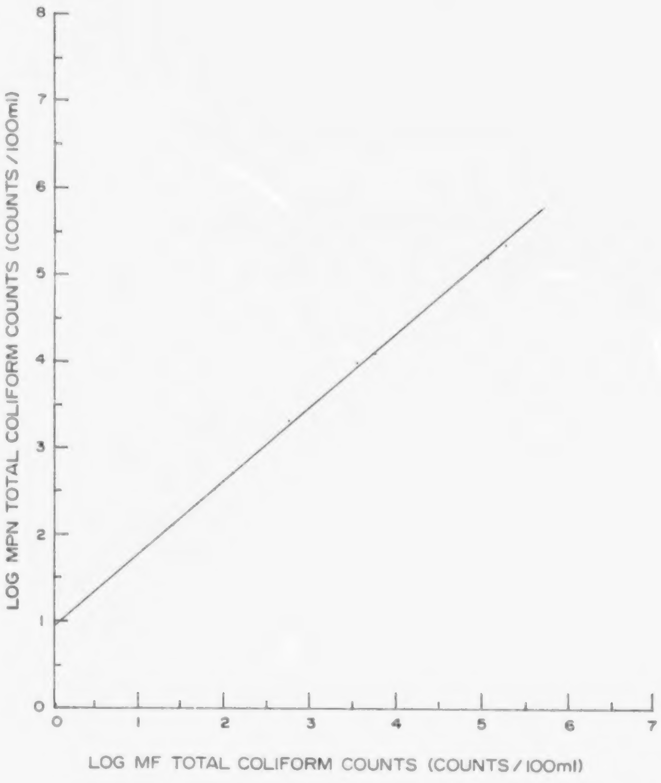

Figure H-14. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for July, 1976.

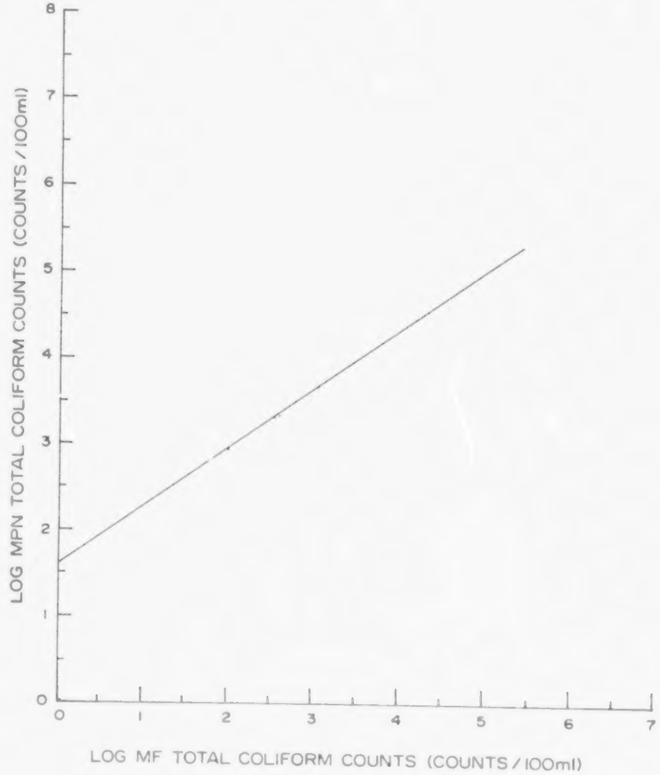

Figure H-15. The relationship between the log of the total coliform concentration determined by the MPN technique and the log of the total coliform concentration determined by the MF technique for August, 1976.

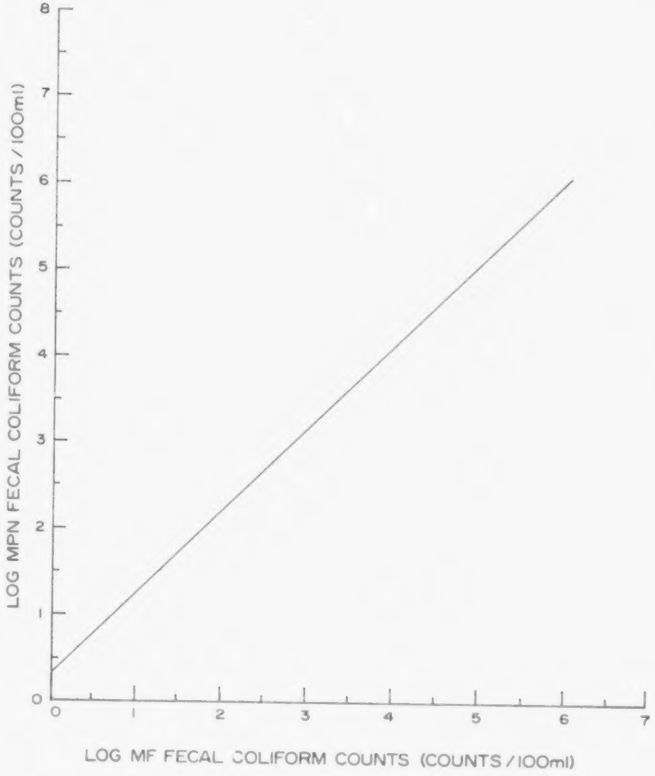

Figure H-16. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for June, 1975.

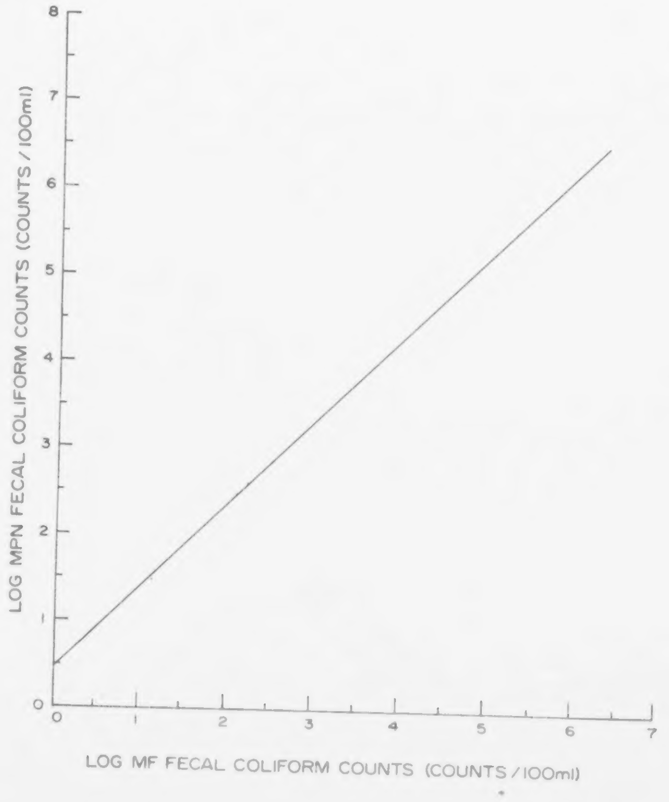

Figure H-17. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for July, 1975.

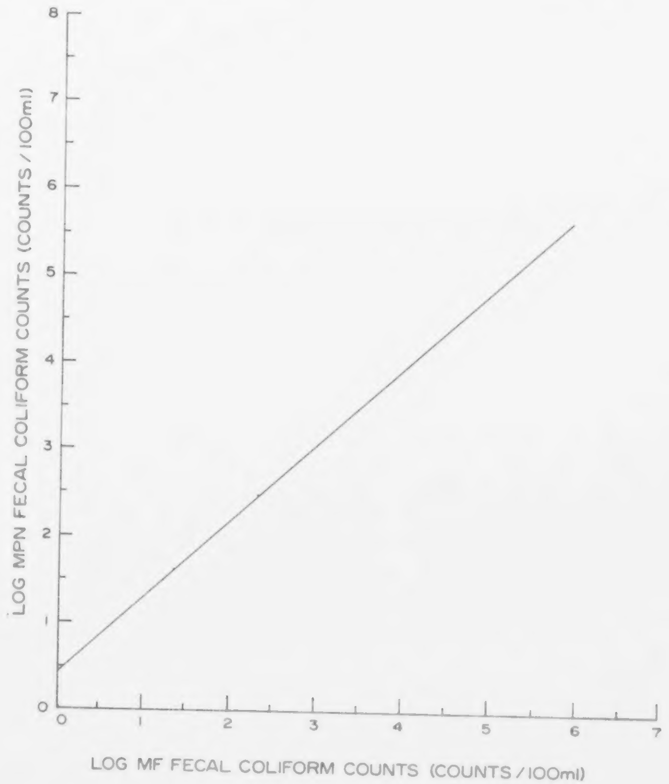

Figure H-18. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for August, 1975.

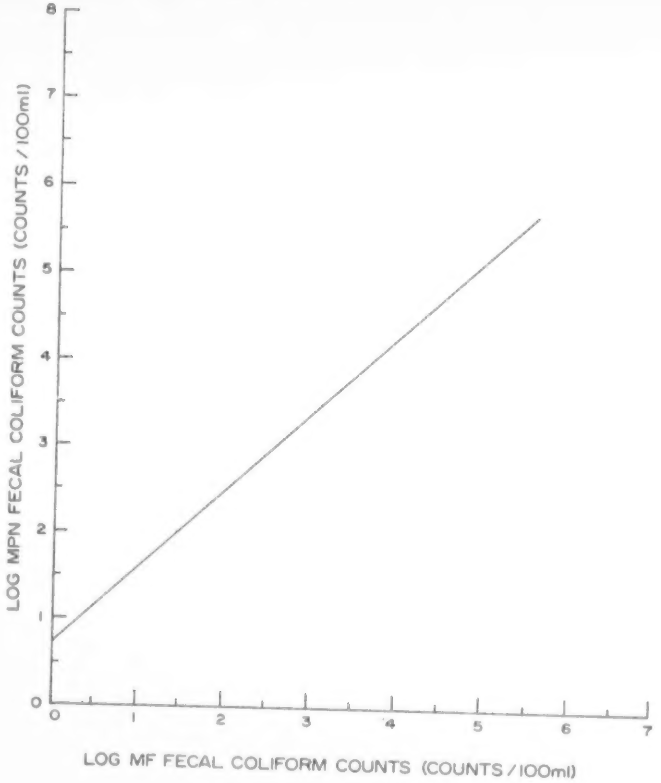

Figure H-19. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for September, 1975.

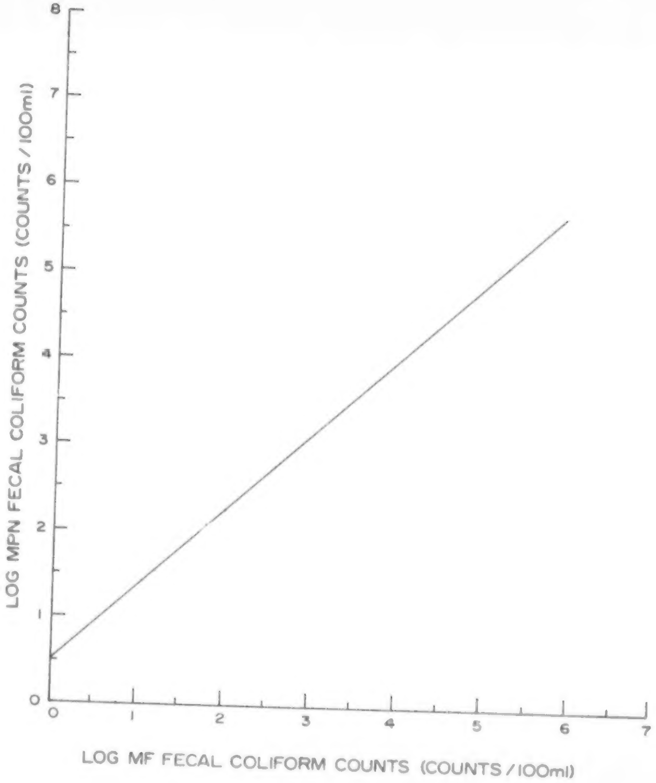

Figure H-20. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for October, 1975.

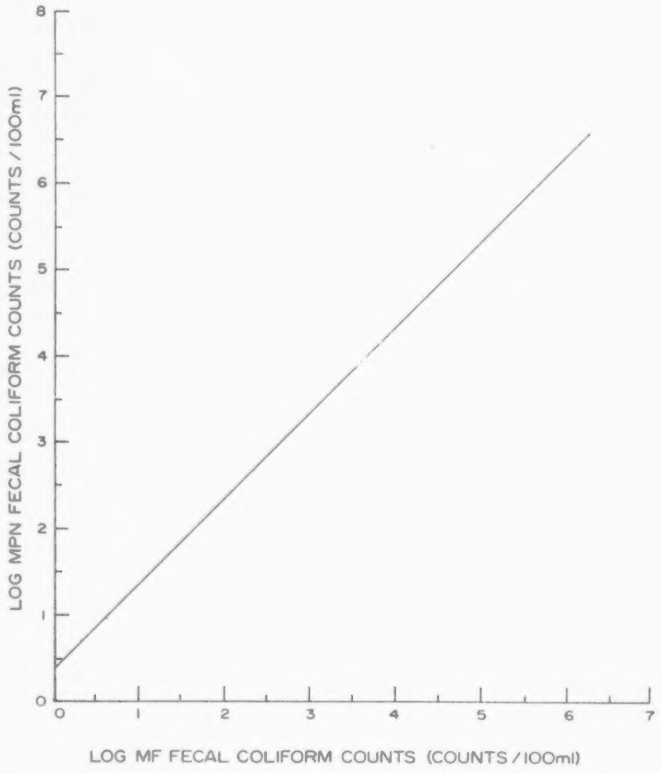

Figure H-21. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for November, 1975.

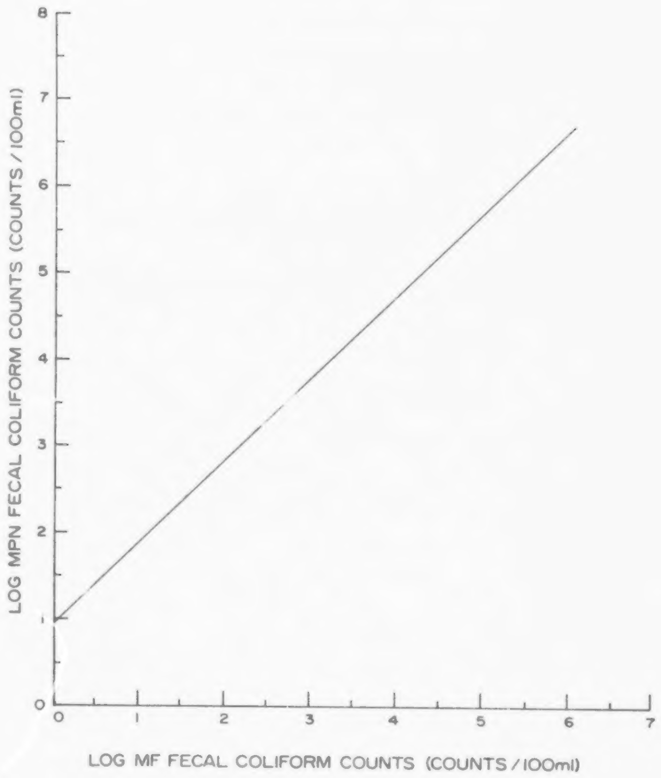

Figure H-22. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for December, 1975.

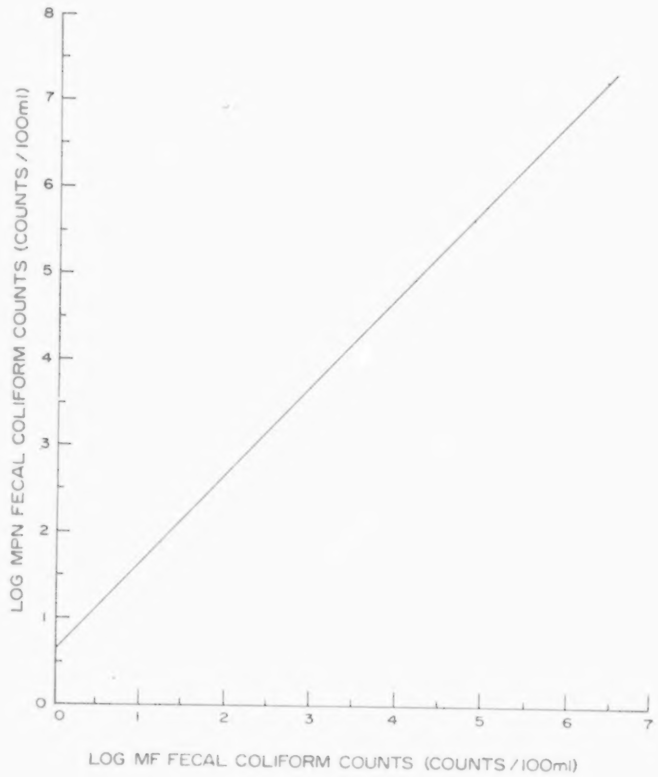

Figure H-23. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for January, 1976.

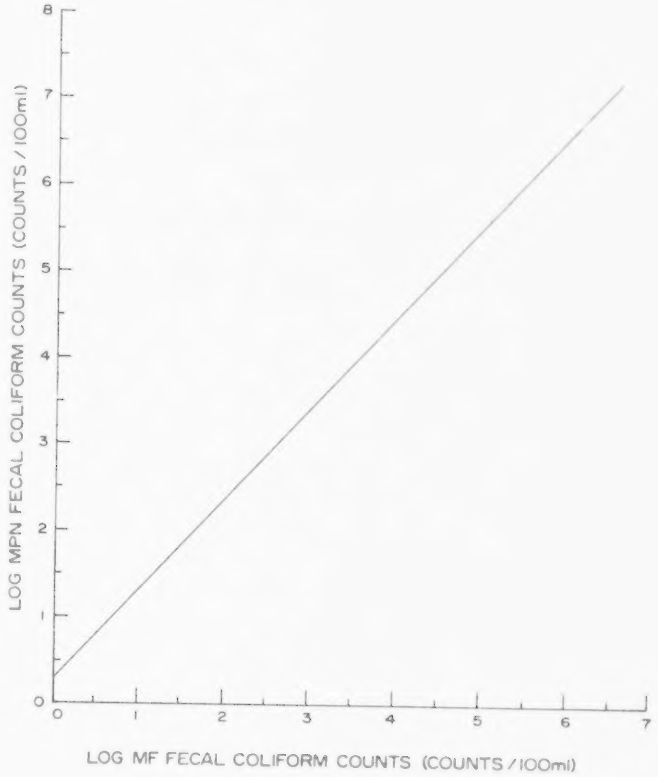

Figure H-24. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for February, 1976.

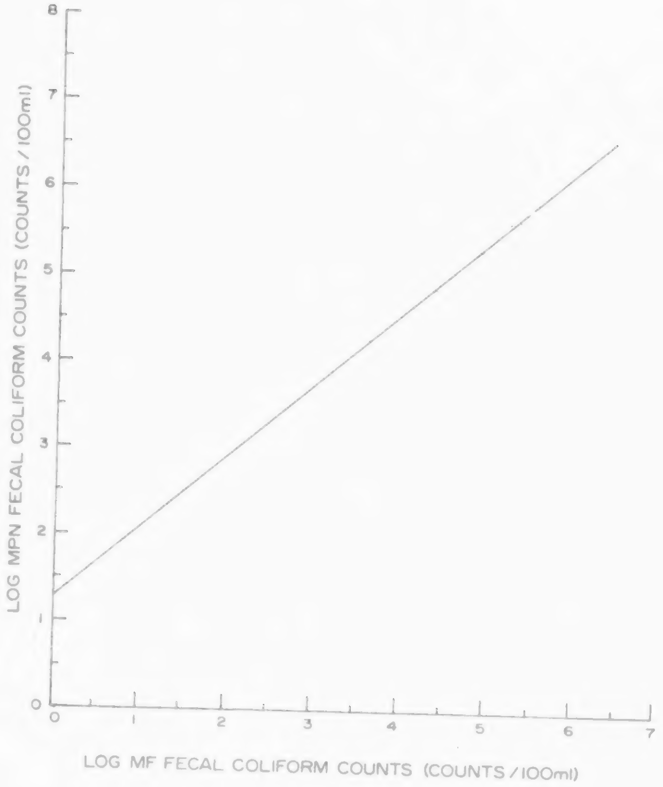

Figure H-25. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for March, 1976.

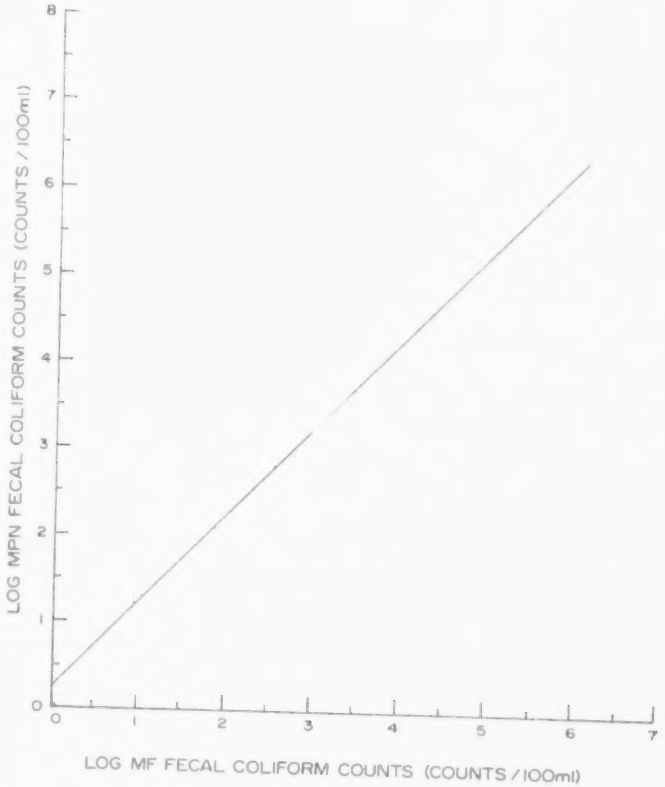

Figure H-26. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for April, 1976.

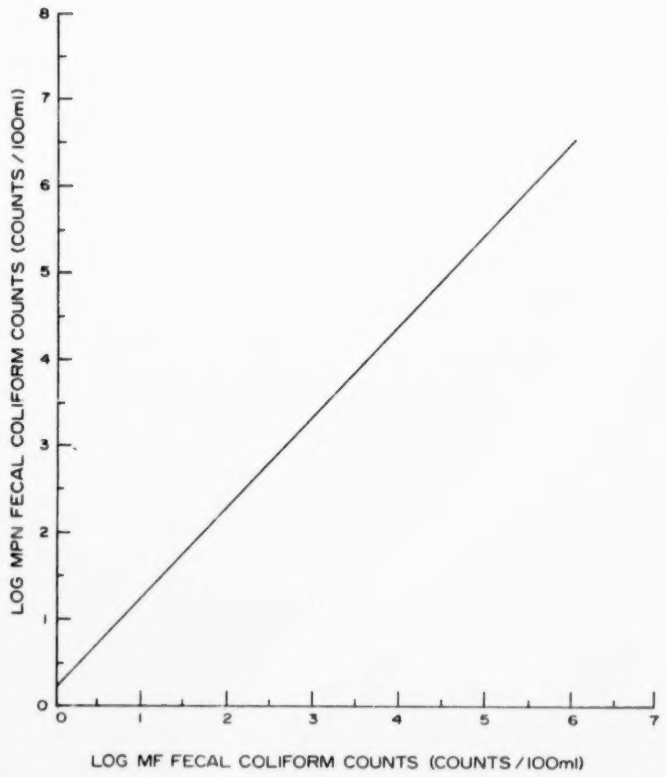

Figure H-27. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for May, 1976.

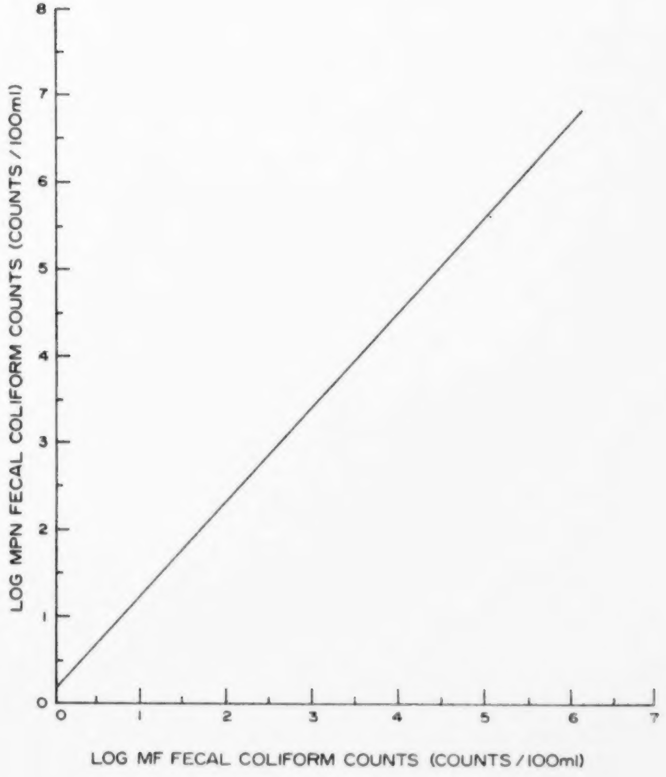

Figure H-28. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for June, 1976.

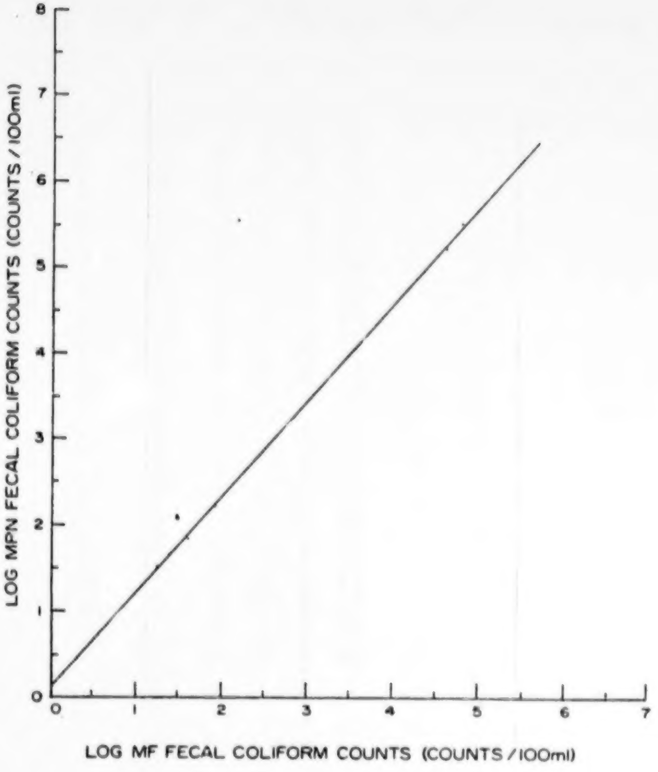

Figure H-29. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for July, 1976.

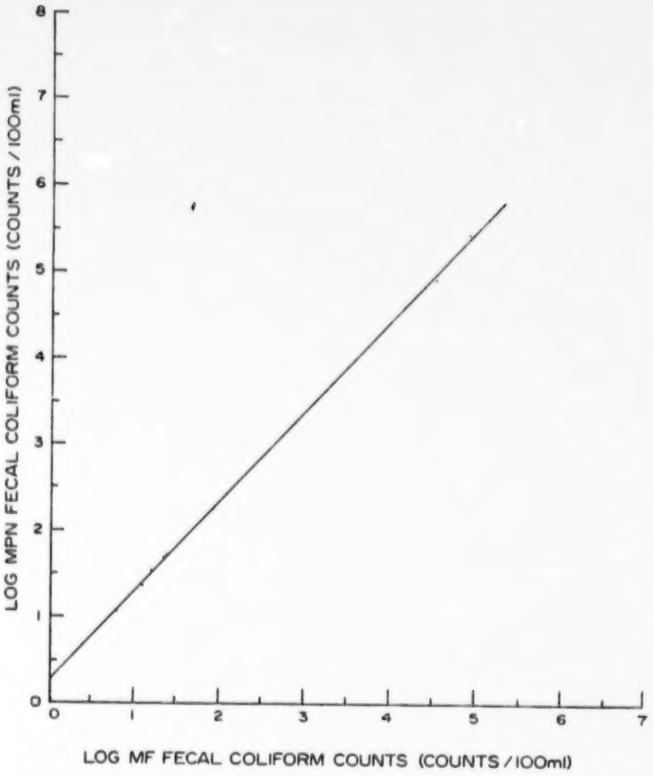

Figure H-30. The relationship between the log of the fecal coliform concentration determined by the MPN technique and the log of the fecal coliform concentration determined by the MF technique for August, 1976.